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Vice-President....................J. E. KNOTT
Sectional Chairmen.......... A. L. SCHRADER, *Pomology*; R. A. MCGINTY, *Vegetable Crops*; S. L. EMSWELLER, *Ornamental Horticulture*
Secretary-Treasurer....................H. B. TUKEY

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LEIF VERNER, *Chairman*
S. H. CAMERON, *Vice-Chairman*
L. H. POLLARD, *Secretary*

SOUTHERN REGION

B. L. WADE, *Chairman*
OTIS WOODWARD, *Vice-Chairman*
J. B. EDMOND, *Secretary*

NEW ENGLAND REGION

A. F. YEAGER, *Chairman*
H. A. ROLLINS, *Secretary*
J. H. WARING, *Vice-Chairman*

GREAT PLAINS REGION

L. E. LONGLEY, *Chairman* M. F. BABB, *Vice-Chairman* JOHN WALKER, *Secretary*

EXECUTIVE COMMITTEE

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R. A. MCGINTY
S. L. EMSWELLER
LEIF VERNER
B. L. WADE
HAROLD MATTSON
A. F. YEAGER
S. H. YARNELL (1946)
F. S. HOWLETT (1947)

MEMBERSHIP COMMITTEE

H. A. CARDINELL, *Chairman*
C. L. VINCENT
ROY MAGRUDER
F. F. WEINARD
R. A. SCHROEDER

BIOLOGICAL ABSTRACTS

J. S. BAILEY (1947)
J. H. MACGILLIVRAY (1947)

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V. A. TIEDJENS
R. M. SMOCK
R. L. CAROLUS

COMMITTEE ON EDUCATION

M. J. DORSEY, *Chairman*
J. H. GOURLEY
C. H. MAHONEY
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G. W. ADRIANCE
R. A. MCGINTY
KENNETH POST
E. C. VOLZ

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F. S. JAMISON
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L. L. CLAYPOOL
O. C. ROBERTS
L. L. MORRIS

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J. H. GOURLEY
A. J. HEINICKE

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F. S. HOWLETT (1949)
G. F. POTTER (1946)
K. C. BARRONS (1948)
HENRY MUNGER (1947)

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W. H. UPSHALL

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B. L. WADE
ORA SMITH
S. H. CAMERON
L. E. LONGLEY

NATIONAL RESEARCH COUNCIL

F. P. CULLINAN

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and

*As revised and adopted at the Philadelphia meeting, January 1, 1941.

junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SOCIETY AFFAIRS

RESUMÉ OF THE MEETING OF THE AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE, ST. LOUIS, MISSOURI, MARCH 28, 29, AND 30, 1946

The American Society for Horticultural Science held its annual meeting in a three-day session at St. Louis, Missouri, March 28, 29, and 30, 1946 in eleven sectional meetings and three joint sessions, together with two evening sessions.

The nature of the discussions and the interest in the various phases of horticulture are shown by the grouping of the papers into general sessions on fruit crops, physiology of vegetables, physiology of fruits, ornamental horticulture, fruit storage and processing, chemical weed control, propagation, nut crops, and small fruits. The joint sessions were with the Biometrical Section of the American Statistical Association on "Plot Arrangement"; with the American Phytopathological Society on "Potato Diseases"; and with Section O, the American Society of Plant Physiologists, and the Physiological Section of the Botanical Society of America on "Mineral Nutrition of Plants and Animals". Round table discussions dealt with teaching methods, extension methods, and maintenance of plant genetic stocks throughout the world for breeding of fruits, vegetables and ornamentals. An additional session treated of physiological changes in fruits and vegetables in consumer packages.

Officers elected for 1946 were as shown on page vii.

The banquet and social evening was in charge of the Missouri group, with Professor T. J. Talbert as chairman and toastmaster. Most interesting entertainment was provided by the music and dancing of a group of local farm folk.

RESUMÉ OF THE MEETING OF THE NEW ENGLAND REGION

The New England Regional meeting was held at Massachusetts State College, December 27 and 28, 1945. There were 31 papers presented, in six sections. There were 30 persons in attendance. Officers elected for 1946 were A. F. Yeager, Chairman, J. H. Waring, Vice-chairman, and H. A. Rollins, Secretary.

RESUMÉ OF THE MEETING OF THE SOUTHERN REGION

The seventh annual and the first post-war Southern Regional meeting was held at New Orleans on February 5, 6 and 7, 1946. This meeting consisted of three working conferences, namely, Co-operative Work on Human Nutrition with Home Economists and Biochemists with Dr. Mary Speirs as chairman, Development of Vegetable Variety Trials with Dr. B. L. Wade as chairman, and Coordination of Research with Small Fruits and Muscadine Grapes with Dr. G. M. Darrow and Dr. F. F. Cowart as chairmen. All conferences were well attended.

The banquet and social evening was held at Arnaud's Restaurant with Dr. J. C. Miller as toastmaster. Distinguished guests were Dr. T. H. McHatton, past-president of the Society, and Mr. Lloyd J. Cobb of New Orleans. The following officers were elected for 1946–47: Chairman, Dr. B. L. Wade; Vice-chairman, Mr. Otis Woodward; Secretary, Dr. J. B. Edmond; members of the Executive Committee, Dr. W. S. Flory (1947), Dr. H. B. Cordner (1948), and Mr. T. E. Ashley (1949).

RESUMÉ OF THE MEETING OF THE WESTERN REGION

A highly successful meeting of the Western Region was held at Reno, Nevada, June 19, 20, and 21, 1946, in conjunction with the Pacific Division of the A.A.A.S. Six sessions were held, involving 27 papers, and including joint sessions with the plant physiologists and soil scientists. There were 43 present at the dinner meet-

ing, which the Chairman of the Western Region, Dr. Leif Verner, addressed on "How Well are We Serving our Constituents".

Officers elected were Chairman, Leif Verner; Vice-Chairman, S. H. Cameron; Secretary-Treasurer, L. H. Pollard.

RESUMÉ OF THE MEETING OF THE GREAT PLAINS REGION

The Great Plains group met at the University of Minnesota on August 27, 28, and 29, 1945 for an interesting program of demonstrations, field tours, and discussion. About fifty were in attendance. The following officers were elected: L. E. Longley, Chairman; M. F. Babb, Vice-chairman, and John Walker, Secretary.

SECRETARY'S REPORT (MARCH 30, 1946)

The American Society for Horticultural Science has apparently come through the war years in good condition, at least so far as finances, membership, printing of the PROCEEDINGS, and general affairs are concerned. At this time the membership in good standing numbers 917. Many service men are returning to their duties and being reinstated, so that the membership in the near future should show a gain.

The financial balance, as of December 31, 1945, showed $9,761.74, as compared with $7,951.69 at the close of the year 1944, an increase of $1,810.05. Expenses for the year 1945 were $547.73 less than for the year 1944, partly due to the fact that only one volume of the PROCEEDINGS was published during the year 1945, with consequent reductions in charges for cuts, labor, and so on. The publication of only one volume was due to the fact that an insufficient number of papers were received to justify the publication of two volumes.

TREASURER'S REPORT

Receipts

Dues	$4,905.64	
Reprints, Cuts, and Extra Pages	1,908.48	
Proceedings	1,573.31	
Humphrey Press (sale of Proceedings and reprints)	761.30	
Miscellaneous receipts	64.85	
Interest on Savings Account	72.60	$9,286.18
On Hand December, 1944		7,951.69
		$17,237.87

Expenditures

Printing Proceedings	$5,477.01	
Halftones and etchings	623.15	
Printing reprints	539.54	
Office supplies, labels, etc	35.92	
Secretary's office	457.12	
Postage and express	197.25	
Proceedings purchased for resale	54.20	
Security bond	30.00	
Union Amer. Biol. Soc	10.00	
Public Relations Directory and Yearbook	15.00	
Bank charges	36.94	
		7,476.13
On hand December 31, 1945 —		
East Lansing State Bank	1,403.45	
Geneva Trust Co	8,358.29	9,761.74
		$17,237.87

REPORT OF THE AUDITING COMMITTEE

Report of the Auditing Committee, acting for J. D. Hartman of Indiana and E. F. Palmer of Canada;

This is to certify that we have examined the books of the treasurer and find them in good order.

March 26, 1946

NEWTON L. PARTRIDGE
ROBERT L. CAROLUS

LEONARD H. VAUGHAN MEMORIAL RESEARCH AWARD

The Leonard H. Vaughan Memorial Research Awards in Horticulture for papers appearing in Volumes 44 and 45 of the PROCEEDINGS are as follows: In *Floriculture* to V. T. Stoutemyer, U. S. Plant Introduction Garden, Glenn Dale, Maryland, for his paper "The Influence of Changes in Molecular Configurations of Several Naphthyl Growth Substances on the Rooting Responses of Cuttings". In *Vegetable Gardening* to P. W. Zimmerman and A. E. Hitchcock, Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York for their paper "Substances Effective for Increasing Fruit Set and Inducing Seedless Tomatoes".

L. H. MACDANIELS
F. C. BRADFORD
J. C. MILLER
W. P. TUFTS
J. K. SHAW, *Chairman*

BUSINESS MEETING
REPORT OF THE EXECUTIVE COMMITTEE

1. Careful consideration has been given to all suggestions received from members of the Society.

2. The report of the Secretary-Treasurer and the finances of the Society has been reviewed.

3. The committee voted that because of the acute problems of transportation and the difficulty of providing adequate accommodations for large groups, the incoming officers consider the possibility of easing the situation by holding the next meeting of the Society independent of other societies, perhaps towards the end of November or early in December. Cincinnati and Atlantic City were mentioned as cities for consideration.

4. After careful consideration of the PROCEEDINGS and the 4-page limit, the Committee voted to continue the regulations now in force, but calling attention to the fact that publication at $5.00 a page for papers which exceed the 4-page limit is a very economical publication.

5. It was voted that a committee of W. H. Alderman, H. C. Thompson, and H. B. Tukey be asked to study the Constitution and By-Laws of the Society and report to the Executive Committee prior to the next meeting of the Society, on a plan to distribute the load of the Secretary-Treasurer. It was voted that in the interim the Secretary-Treasurer be empowered to delegate some of his duties to others.

6. The Executive Committee adopted the following motion: "The Executive Committee of the American Society for Horticultural Science recognizes the value of the services rendered by the National Joint Committee on Fertilizer Application, which comprised representatives of the fertilizer industry, the equipment manufacturers, the Society of Agricultural Engineers, the American Society of Agronomy, and the American Society for Horticultural Science. The Executive Committee feels that the action taken at the meeting of the American Society of Agronomy at Columbus, Ohio, February 26, 1946, in reorganization of the National Joint Committee on Fertilizer Application, in which the American Society for Horticultural Science was not consulted, was such as to jeopardize the usefulness of this committee. The Executive Committee asks that this action be reconsidered and that the organization and functions of the original National Joint Committee on Fertilizer Application be restored."

7. The Nomination Committee nominated by the Executive Committee for vote of the Society is: J. H. Gourley, *Chairman*, H. A. Rollins, B. L. Wade, Ora Smith, S. H. Cameron, and L. E. Longley.

Report of the Secretary-Treasurer: The report was accepted.

Committee on Varieties: The report of the committee on Varieties was accepted and the committee discharged.

Auditing Committee: The report of the Auditing Committee was accepted.

Committee on Education: The committee report was accepted, including the request that a permanent committee be appointed. It was voted to ask the temporary committee to continue its services in the interim.

Extension Workers: The request of Extension workers was favorably voted that the Program Committee consider the possibilities of holding a round-table for extension workers, perhaps the evening before the regular three-day session of the Society.

Committee on Consumer Packages and Pre-Packaging: Upon motion it was voted that the Society consider the feasibility of a session on the physiological aspects of consumer packages at the next annual meeting of the Society, and that a committee be appointed to coordinate the efforts of horticulturists working in this field. The committee as appointed is: R. L. Carolus, *Chairman*, H. C. Thompson, L. E. Scott, J. H. Gourley, C. O. Brately, F. S. Jamison, F. C. Gaylord, L. L. Claypool, O. C. Roberts, and L. L. Morris.

Nominating Committee: The Nominating Committee presented the names for the various offices as printed in the list of officers in this PROCEEDINGS.

Resolutions Committee: The resolutions presented by the Resolutions Committee and adopted by the Society were:

1. The Society heartily endorses the action of the National Research Council in proposing to Sir John Orr, Director General of the United Nations Food and Agriculture Organization that as a safeguard to the welfare of all peoples, steps be taken as soon as possible to collect and maintain the plant and animal materials likely to be of service in breeding.

We further resolve that the members of the National Research Council Committee on Plant and Animal Stocks who are working with horticultural crops constitute a committee of the Society to work with the National Research Council in furtherance of this program.

2. Be it resolved that the American Society for Horticultural Science express its sincere appreciation of the friendliness and cooperation of the hotel managements of St. Louis, who have provided us with excellent facilities despite the abnormal congestion.

3. Resolved that the American Society for Horticultural Science express its appreciation to Dr. C. H. Mahoney and the Program Committee for its splendid service in arranging a well organized program under unusually difficult circumstances.

4. Be it resolved that the American Society for Horticultural Science commend Professor T. J. Talbert and his coworkers on the Committee for Local Arrangements.

H. P. OLMO
A. F. YEAGER
B. L. WADE, *Chairman*

The Relation of Total Leaf Nitrogen to the Yield and Color of Stayman Winesap Apples at Different Rates of Nitrogen Fertilizer Applications on Sod

By I. W. WANDER, *Ohio Agricultural Experiment Station, Wooster, Ohio*

EXPERIMENTS designed to evaluate the effect of various amounts of nitrogen fertilizer applications on the yield and color of fruit from Stayman Winesap apple trees in sod have been in progress at the Ohio Station since 1928. Recently, analyses were made of the total nitrogen content of leaf tissue from the differentially treated trees in order to determine if there is any relationship between such analyses and previously obtained yield and color records. It was believed that an index of the nitrogen status of Stayman Winesap trees would thus be defined and that such knowledge would be useful in ascertaining whether commercial plantings were receiving too little, adequate or too much nitrogen to produce optimum yield and color.

Other investigators (4, 1, 2, 3) have shown that definite relationships exist between nitrogen fertilizer applications, total leaf nitrogen, and yield and color of the fruit of Rome Beauty and McIntosh. It is the purpose of this report to give the relationships existing for the variety Stayman Winesap.

TREATMENT, SAMPLING, AND ANALYTICAL PROCEDURES

The total nitrogen content of Stayman Winesap leaves was determined from trees growing in blue grass sod, cultivation with cover crops, and heavy straw mulch at three nitrogen levels. The nitrogen levels were: untreated, normal application (¼ pound of $NaNO_3$, or equivalent in nitrogen, per tree per year of tree's age), and triple this amount. These three nitrogen levels have been maintained continuously on the sod plots since 1928. The cultivation with cover crops and the straw mulch plots have had two nitrogen levels, untreated and normal nitrogen since 1924. Triple nitrogen was used on the cultivation with cover crops and straw mulch plots only in 1944 and 1945. For this reason, although leaf analyses were made, previous yield and color records are not available on these two systems of culture with triple nitrogen.

All nitrogen applications were made in the spring of the year just as growth started and all trees and treatments are located on the Wooster silt loam soil.

Leaf samples were taken in the experimental plots several times during the growing season from the mid portion and at the base of the current years growth. Approximately 100 leaves from a tree constituted a sample, three trees in each treatment being sampled. Samples from commercial orchards were taken only once during the summer, July 30 to August 3, 1945, and consisted of the mid leaves of the shoots.

Nitrogen determinations were made by a modification of the Kjeldahl procedure using selenium as a catalytic agent in digestion.

Results and Discussion

The previous records of yield and color of Stayman Winesap fruit from the differently fertilized plots under different systems of culture are given in Tables I and II. These records show that the use of excess nitrogen fertilizer on sod resulted in decreased yield and less well colored fruit whereas a lack of nitrogen resulted in greatly reduced yield but well colored fruit compared to the normal nitrogen treatment. The normal or recommended nitrogen application (¼ pound $NaNO_3$ or equivalent per tree per year of trees age) resulted in the highest yield with the color grades averaging between the fruit from no nitrogen and triple nitrogen plots.

TABLE I—The Relationship of Cultural and Nitrogen Fertilizer Treatments to the Yield of Stayman Winesap During a Period of 14 Years

	Treatment	Average Yield Per Tree Per Year (Pounds)
	Orchard J 1930–1943	
C	Sod, check	221.4
N	Sod, normal nitrogen	423.9
NNN	Sod, triple nitrogen	355.9
	*Orchard C 1923–1936**	
C	Cultivation with cover crops, check	517.4
N	Cultivation with cover crops, normal nitrogen	542.5
C	Heavy straw mulch, check	531.7
N	Heavy straw mulch, normal nitrogen	514.6

C = Check (no nitrogen fertilizer)
N = Normal nitrogen (¼ lb. $NaNO_3$ or equivalent per tree per year of tree's age.)
NNN = Triple nitrogen (three times the normal application)
*It was necessary to use the yield records for this period of years in order to have comparable tree ages. Acknowledgement is made to C. W. Ellenwood and T. E. Fowler of the Ohio Station for the yield and color data from Orchard C.

TABLE II—The Relationship of Cultural and Nitrogen Fertilizer Treatments to the Color Grades of Stayman Winesap During a Period of 14 Years, 1930–1943

	Treatment*	Color (Per Cent)		
		33+	15 to 33	15−
	Orchard J			
C	Sod, check	94.7	4.0	1.3
N	Sod, normal nitrogen	79.4	15.2	5.4
NNN	Sod, triple nitrogen	68.7	19.7	11.6
	Orchard C			
C	Cultivation with cover crops, check	82.2	13.5	4.3
N	Cultivation with cover crops, normal nitrogen	79.7	15.3	5.0
C	Heavy straw mulch, check	77.7	15.0	7.3
N	Heavy straw mulch, normal nitrogen	76.8	16.5	6.7

*Treatments are the same as in Table 1.

The differences in yield and color with respect to nitrogen application are more pronounced with trees in sod than with trees under the straw mulch or cultivation with cover crops systems of culture. Apparently these systems of culture result in sufficient available nitro-

gen to prevent a depression in yield on the check plots which received no nitrogen fertilizer.

The percentages of total nitrogen, on a dry weight basis, in the leaf tissue of trees in sod receiving different amounts of nitrogen fertilizer are shown in Fig. 1. Increases in the total nitrogen content of the

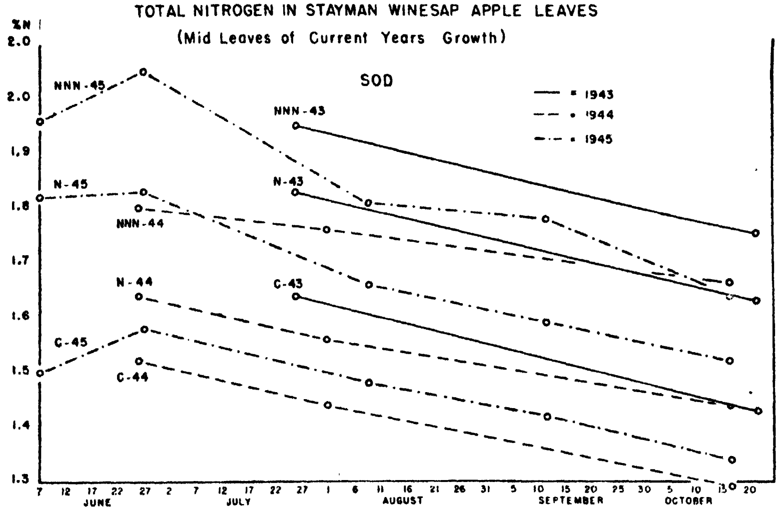

FIG. 1. The effect of the nitrogen treatments; C (no nitrogen fertilizer), N (¼ pound $NaNO_3$ or equivalent per tree for each year of the tree's age), and NNN (triple the N application) on the total nitrogen content of Stayman Winesap leaves from trees in sod during the growing season for a 3-year period.

leaves were found to be directly related to increases in nitrogen applications on sod. Smaller differences were noted when nitrogen was used in conjunction with straw mulch (established 30 years) or with cultivation with cover crops systems of culture as seen in Figs. 2 and 3. Leaves from untreated plots (receiving no nitrogen as fertilizer) under these two systems of culture contained relatively large amounts of total nitrogen, equivalent to or in excess of that found in leaves from trees on sod receiving a normal nitrogen application.

The total nitrogen content of leaves from all treatments decreased as the season progressed. This decrease was more uniform in the sod and cultivation with cover crops systems of culture than in the straw mulch plots.

These results indicate that analyses, in order to be comparable, must be made at the same time during the growing season and results from one system of culture are not comparable with those from another system.

Analyses for total nitrogen in the base leaves of shoots followed the same pattern as for the mid leaves but on a lower scale. Since no advantage is gained in using base leaves of shoots, mid leaves (of shoots) would appear to be the best ones to sample.

The range of differences in total leaf nitrogen from trees under all

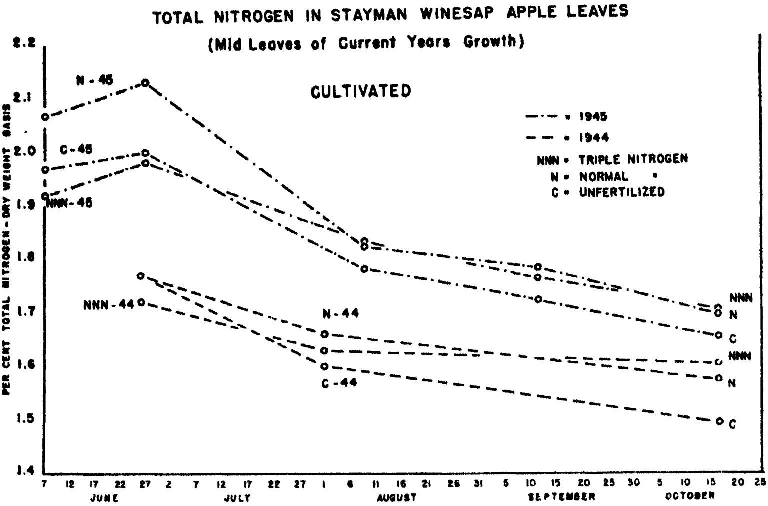

FIG. 2. The effect of the nitrogen treatments, C (no nitrogen fertilizer), N (¼ pound $NaNO_3$ or equivalent per tree for each year of the tree's age), and NNN (triple the N application) on the total nitrogen control of Stayman Winesap leaves from trees in cultivation with cover crops during the growing season for a 2-year period.

treatments during a three year period indicate that the amount of nitrogen in the leaves for any 1 year depends on the fruit crop for that year. In 1943, with a small crop, the nitrogen content of the leaves

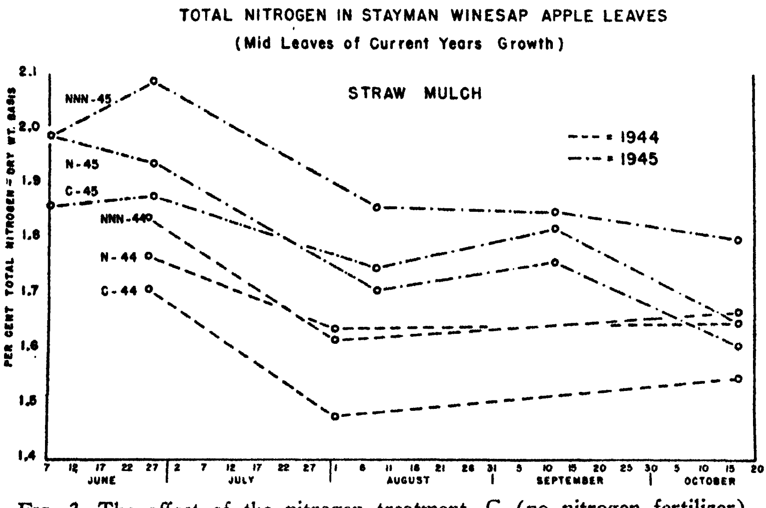

FIG. 3. The effect of the nitrogen treatment, C (no nitrogen fertilizer), N (¼ pound $NaNO_3$ or equivalent per tree for each year of the tree's age), and NNN (triple the N application) on the total nitrogen content of Stayman Winesap leaves from trees in heavy straw mulch during the growing season for a 2-year period.

from all treatments in sod was relatively higher than in 1944 with a heavier crop and up again in 1945 with no crop. The same relationship existed in the straw mulch and cultivation with cover crops systems of culture.

From these results it is apparent that, any range or extent of limits of total leaf nitrogen, to be correlated with yield and color will depend on time of sampling, size of crop and system of culture. That there is a varietal difference is also noted from the range found by Boynton (3) for McIntosh as compared to the range herein reported for Stayman Winesap.

The analyses for total nitrogen of 31 Stayman Winesap samples taken from 28 commercial orchards in Ohio during the last week in July and first week in August 1945 are shown in Fig. 4. The limits

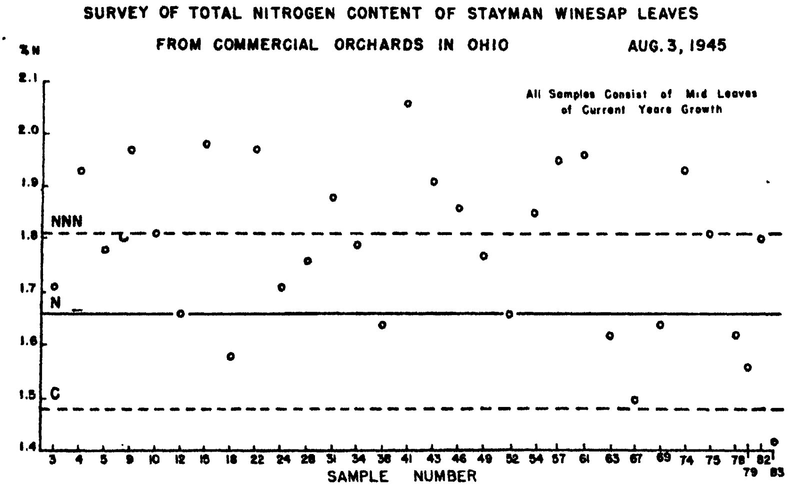

FIG. 4. The total nitrogen content of Stayman Winesap leaves from commercial orchards in Ohio compared with range of limits found in the experimental sod plots at Wooster, Ohio.

or range of leaf nitrogen, as indicated by horizontal lines in this figure, resulted from analyses of leaf samples taken from the sod orchard at the experiment station. The samples from the commercial orchards and those from the experimental plots were taken within a 2-week period. Analysis of samples from commercial orchards, when plotted against the range of leaf nitrogen found at Wooster indicate that out of the 31 Stayman Winesap leaf samples studied four would benefit with respect to yield from the use of more nitrogen, eight are about optimum and 19 are too high in nitrogen to result in good color. This may be partially the reason why many greenish and muddy colored Stayman Winesap are produced. There are, of course, a number of other factors affecting color such as light, day and night temperatures, moisture supply, etc., but undoubtedly in many cases fruit color is correlated with the nitrogen status of Stayman Winesap trees as reflected in leaf analysis.

Summary

Previous records of yield and color of fruit bear a relationship to the total nitrogen content of Stayman Winesap apple leaves taken from trees growing on the Wooster silt loam soil under different cultural treatments and nitrogen applications. Through previous records it was known that excessive nitrogen fertilizer on sod resulted in a depression of yield and more poorly colored apples compared to the recommended nitrogen application of ¼ pound of $NaNO_3$ or its equivalent in nitrogen, per tree for each year of the tree's age. A lack of nitrogen on sod resulted in greatly reduced yields but well colored fruit. These effects were more pronounced in sod than in the straw mulch or cultivation with cover crops systems of culture because these systems apparently provided enough available nitrogen to prevent a depression in yield on the check or untreated plots.

The total nitrogen of leaves from all treatments decreased as the growing season progressed, the decrease being more uniform in the sod and cultivation with cover crops systems of culture than in the heavy straw mulch system. The nitrogen content of base leaves of shoots followed the same pattern as for the mid leaves, but on a lower scale. A difference in the amount of nitrogen in leaves from all treatments was noted depending on the size of crop carried by the trees. Larger amounts of nitrogen were found in leaves from trees bearing little or no crop as compared to the same trees under the same treatment bearing a full crop.

Results of analyses of 31 Stayman Winesap leaf samples from commercial orchards in Ohio when compared to analyses of leaves from the experimental sod plots at Wooster indicate that four locations would benefit from additional nitrogen, eight are about optimum and nineteen are high enough in nitrogen to result in detrimental effects on fruit color and possibly yield. Although 1 year's data cannot be used as a basis for a definite conclusion, these results suggest a reason for the lack of color in Stayman Winesap production.

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Performance of a Pear Orchard with Flooded Soil

By J. R. Kienholz, *Department of Agriculture, Hood River, Oregon*

A pear and apricot orchard along the Columbia River, near Hood River, Oregon, has been flooded for varying periods since the filling of the Bonneville Dam basin in 1943. This condition provided an unusual opportunity to observe fruit-tree response to partial or complete flooding, since in 1941 there were 320 Anjou and 535 Bartlett trees 11 years old and 60 Tilton apricot trees of the same age in the planting.

The soil surface in this orchard varies from 74 to 82 feet above sea level. It is evident, therefore, as shown in Fig. 1, that the initial rise

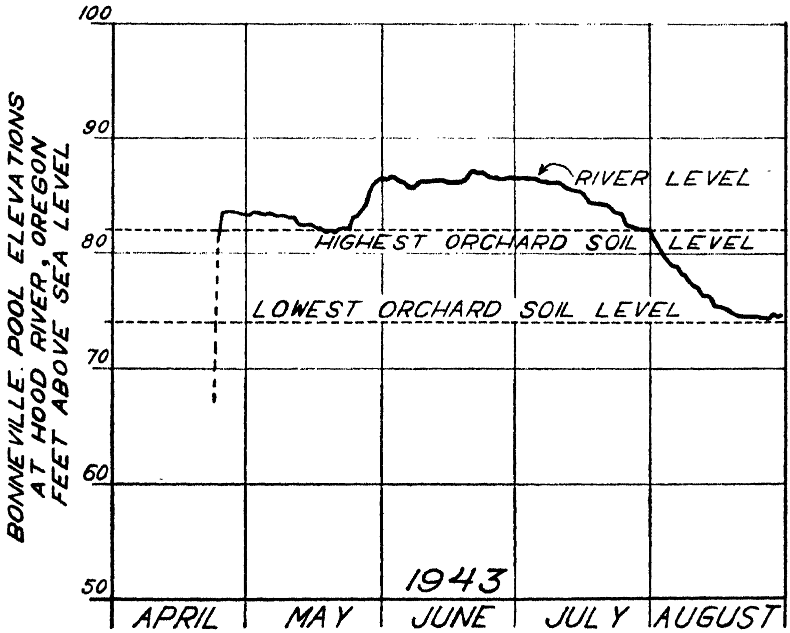

Fig. 1. Flood stage in Koberg pear orchard—1943.

of the water level to 83.4 feet in April, 1943, and subsequently to a maximum of 87 feet during June and July completely submerged all the soil on which the trees were growing.

When the water level was at its maximum, the soil in the lowest part of the orchard was submerged to a depth of 13 feet. The water level did not start to drop until August, with the result that the lowest part of the orchard had been submerged for more than 4 months and the highest portion for approximately 3 months.

Between the 1943 and the 1944 growing seasons a dike was constructed at the lower end of the orchard and a motor-driven pump was operated in an effort to keep the water in the orchard below 70

feet. However, in 1944, because of a higher lake level than was anticipated, the water in the orchard remained above 75 feet much of the time. When the lake level reached 83 feet during the summer of 1944, the water level in the orchard was 78.5 feet. On August 29, when the lake level was at 79 feet, the water in the orchard was down to 75.5 feet. Thus it will be seen that only the highest land in the orchard was free from water during the whole season of 1944. In 1945 the lake level increased from 76 feet on April 5 to a maximum of 87.5 feet on June 9, and then gradually receded to below 75 feet by July 15.

Confronted by these unusual conditions, the owner mounted a spray machine on a barge and continued with his regular disease and insect spray program (Fig. 2).

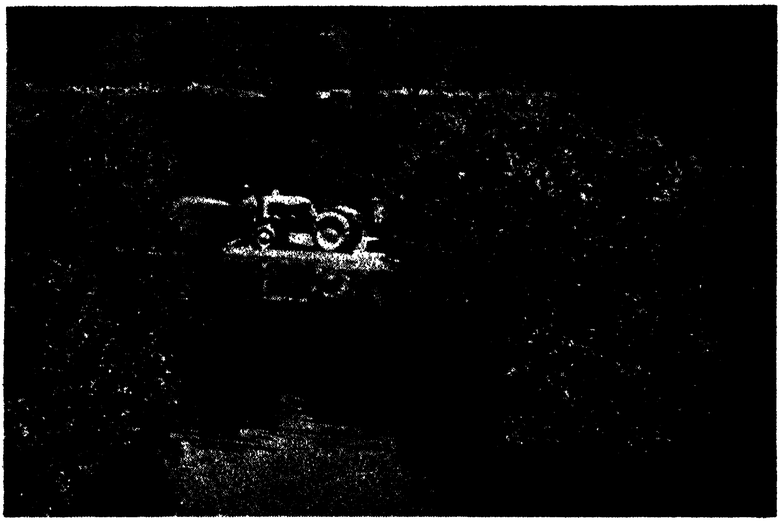

Fig. 2. Spraying operations in the flooded Koberg pear orchard.[1]

On land below the 76-foot elevation the water table has been at or close to the surface, except for periods during fall to late spring of 1943–45. A few pear trees at the lowest soil levels in the orchard died during 1943, and many appeared girdled. On the land between the 76 and 80 foot levels only an occasional tree was dead by the end of 1945. Dorsey and Ruth (2) report somewhat similar results in an apple orchard near Hillview, Illinois, which was flooded by the Illinois River at intervals from October 5, 1926 to February 1, 1927. In this Illinois orchard, the tops of the trees were covered by the flood waters on October 12, before the leaves had shed, and again on November 30; yet the following spring Dorsey and Ruth found that very few trees were killed except in one corner of the orchard. In this area, which was the lowest and most fertile portion of the orchard, they believed a drop in temperature to −22 degrees F on January 15, 1927

[1]From a Kodachrome picture taken by A. L. Marble, County Agent, Hood River, Oregon.

during a period when the flood had subsided, was largely responsible for the death of the trees rather than the high water.

A fairly sharp line of demarcation in respect to condition of the pear trees occurs at approximately the 78-foot elevation in the Koberg pear orchard at Hood River, Oregon. Below that level both Bartlett and Anjou trees have made little terminal growth. Nearly all Bartlett trees in this zone show definite girdling and may eventually die. Above the 78-foot level the Anjou trees showed practically no injury, the terminal growth in 1944 averaging 18 to 24 inches. Many of the Bartlett trees above the 78-foot level failed to produce good terminal growth, and often showed injury in the form of girdled trunks, split bark, or dieback. Because cold injury to pear trees occurred rather generally in the Hood River Valley in the winter of 1942, the visible injury to pear trees in this orchard in 1943 was probably a combination of flooding and winter injury. Many of the lower tree limbs that appeared to have been injured by long immersion in the water later produced new shoots and seemed to recover. Other trees showing more trunk and limb splitting often showed overgrowths at the highest point of injury.

The single row of apricot trees, even though it was located on some of the highest ground in the orchard, died within 2 weeks after being flooded in 1943. This behavior of the apricot trees is in accord with the widely recognized susceptibility of species of Prunus to waterlogging of the soil. The observations by Fikry (3, 4, 5) in the Nile Delta of Egypt has shown how rapidly many of these Prunus species succumb to the effects of flooding.

Production records are available for the 2 years previous to the flooded condition and for the 3 years that the orchard has thus far been at least partially flooded. These data are given in Table I.

TABLE I—PRODUCTION RECORD OF THE KOBERG PEAR ORCHARD FROM 1941 TO 1945

Year	Bearing Anjou Pears		Bearing Bartlett Pears	
	Number Trees	Boxes Fruit	Number Trees	Boxes Fruit*
1941	320	1,364	535	1,322
1942	—	1,750	—	2,156
1943**	—	438	—	1,074
1944	311	886†	374	640
1945	283	2,428	278	940

*Converting 40 boxes to the ton.
**Generally short crop in the district. First year of flooding in the orchard.
†Only 440 boxes packed, due to poor quality.

In 1943 the Anjou fruits appeared at harvest to be of normal quality, but during storage a browning started in the core region and progressed outward, so that after being held in storage for approximately 2 months some of the fruits were unfit for sale. No cork spot was observed. Bartlett fruits appeared normal, except for a slight tendency to premature ripening.

In 1944 the Anjou fruits developed cork spot, particularly on trees at the lower soil levels. This cork spot was one of the type showing feathery necrotic streaks in the flesh rather close to the skin surface

and not in the core region. Degman (1) reported that cork spot also appeared in Anjou fruits when trees growing in concrete-enclosed areas were artificially flooded. Some internal breakdown of the fruit occurred before it was picked and was so severe in some fruits that the core separated from the flesh during picking. Such fruits were from obviously injured trees. Many of the Anjou fruits also had large areas of solid russet, with occasionally the entire surface russeted, while other fruits on the same limbs were often russet-free. By marketing this fruit early little loss was experienced from its sale, although sample lots placed in cold storage deteriorated more rapidly than sample lots from unflooded orchards. The Bartletts again showed a tendency to premature ripening in 1944, with some unevenness in coloring. This abnormally early yellowing of the fruit was characteristic of obviously girdled trees. This fruit showed some signs of breakdown or shriveling. The early yellowing of some fruits resembled the early stages of "hard end," but no "hard end" or "black end" developed.

Considerable cork spot was found on obviously injured Anjou trees in 1945, sometimes practically all fruits being affected. Uninjured fruit, however, was of good quality and kept well in cold storage. Bartlett fruits, except those ripening prematurely on injured trees, gave no trouble in the canning process. Picking the fruit at an early maturity date and placing it in cold storage promptly probably were factors in eliminating some of the trouble encountered in 1944.

Summary and Conclusions

The observations in this orchard substantiate the widely recognized greater susceptibility of apricot than of pear to a limited period of soil waterlogging. These observations also indicate that Bartlett pear trees suffered more flooding injury than did Anjou trees, at least following a winter when winter injury occurred in some orchards.

Although almost continuous waterlogging of the soil (in the case of trees at or below the 76-foot level) had killed pear trees by the end of one season, complete submergence of the soil for at least 3 months during each of 3 growing seasons did not kill the trees, but did affect fruit development.

In the case of Anjou, the prolonged but discontinuous submergence during 3 summers resulted in the fruits on the trees developing not only cork spot but also internal breakdown characteristic of fruit senescence in storage. Bartlett fruits on the tree softened and colored earlier than normal, but did not develop hardend or blackend.

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Effect of DDT Spray on Apple Leaf Efficiency

By H. H. Moon and C. P. Harley, *U. S. Plant Industry Station, Beltsville, Md.*

In the commercial use of DDT sprays in apple orchards, no apparent injury directly attributable to this material has been observed by the authors. Leaves with heavy spray deposits of DDT have appeared to be normal in every way. The absence of visible injury, however, is not conclusive evidence that leaf function may not have been affected deleteriously to some degree. To test the possibility of a reduced efficiency of apple leaves sprayed with DDT was the purpose of this study.

Methods

It is generally accepted that the enlargement rate of most fruits is a sensitive measure of leaf metabolism as affected by environment, and the technique adopted for the present study was one involving this principle.

A formulation of 25 per cent of DDT of fine-particle size in 300-mesh clay was suspended in water and sprayed on fruit and foliage of carefully selected branches of York Imperial, Golden Delicious, Delicious, Jonathan, Rome Beauty, and Stayman Winesap apple trees. The concentration of actual DDT was 1.5 pounds in 100 gallons of water. Control branches were sprayed with a suspension of the clay without DDT. Relative leaf efficiency was determined by measuring the circumference enlargement rate of apples on bark-girdled branches having 200 and 300 square centimeters of leaf area per fruit. These surface areas represent approximately the equivalent of 10 medium and 10 large leaves per fruit, respectively. This restricted leaf area per fruit represents a condition wherein the synthesized materials are wholly utilized in fruit growth (2) ; thus, any reduction in leaf activity should be reflected in the enlargement rate of fruit.

Paired branches were used in all comparisons, and each pair originated from similar locations on the main limbs. Y branches were selected wherever possible. One branch or fork of the Y was sprayed with DDT, while the other served as the control. All applications of spray were made on calm days, but further precautions to prevent drift were taken by placing large cardboard baffles between the control and DDT-sprayed limbs. The use of a small hand sprayer in applying the spray also aided in preventing possible contamination.

Rings of bark were removed at points behind the leaf and fruit areas to prevent movement of synthesized materials into or out of the portions under test. No protection was given to the woody tissues exposed by ringing. The diameter of branches at the point of ringing varied from 2.0 to 4.0 centimeters. In making the leaf-fruit adjustments, all small, injured, and poorly developed leaves were removed. The remaining foliage area was then determined by comparing each leaf with an area gauge made from leaf models of known surfaces. After the total area was recorded, fruit or leaves were removed to bring about the desired ratio of leaf surface to fruit. When loss or

injury to fruits occurred, the required leaf area was reduced in order to reestablish the original ratio. Removal of leaves was accomplished by cutting the petioles with small shears. Fifteen pairs of branches were so treated.

The apples were tagged and their circumference measured with a tape at frequent intervals, beginning June 2 and ending July 20, 1945. At the end of the test a total of 514 apples, including all varieties, had been measured. The first measurement date represented a period of 63 days after full bloom. At this time extension growth was completed and leaves were fully developed. In order to permit growth equilibrium to become established in the girdled and leaf-fruit-adjusted branches, DDT was not applied until June 27. A repeat spray treatment then followed on July 7.

Insecticide and fungicide sprays containing arsenate of lead and lime and bordeaux mixture were applied to the experimental trees prior to and during the experiment. Careful observations were made for infestations of leaf-sucking insects such as leaf hoppers and red mites. The presence of leaf hoppers on control branches, for example, might reduce leaf efficiency, which could be erroneously interpreted as a stimulating effect of DDT. Similarly, red mites are not controlled by DDT and their effects could be erroneously interpreted as DDT toxicity. Neither leaf hoppers nor red mites, however, were found on any of the experimental branches.

Results and Discussion

The average fruit growth rates of DDT-sprayed and control branches of all varieties are shown in Fig. 1 A to H.

Since there is no divergence in fruit-enlargement rate between the

TABLE I—Precipitation and Daily Maximum Temperatures Occurring in the Orchard During the Experimental Period

Date	Maximum Temperature (Degrees F.)	Precipitation (Inches)	Date	Maximum Temperature (Degrees F.)	Precipitation (Inches)	Date	Maximum Temperature (Degrees F.)	Precipitation (Inches)	Date	Maximum Temperature (Degrees F.)	Precipitation (Inches)
	June			*June*			*June*			*July*	
2	84	0.93	14	94	—	26	84	—	8	89	—
3	74	—	15	92	—	27*	87	—	9	88	0.11
4	66	—	16	93	—	28	94	—	10	88	1.53
5	63	—	17	94	0.04	29	95	—	11	76	—
6	70	—	18	90	0.64	30	96	—	12	78	—
							July				
7	73	—	19	77	0.15	1	98	—	13	84	—
8	74	—	20	85	—	2	92	1.15	14	82	1.28
9	72	0.58	21	88	2.02	3	81	—	15	76	0.39
10	81	—	22	80	—	4	83	—	16	79	0.35
11	89	—	23	86	—	5	85	0.76	17	71	2.95
12	86	—	24	94	—	6	88	—	18	77	0.58
13	90	0.12	25	86	—	7**	85	—	19	81	0.32

*First DDT spray application
**Second DDT spray application

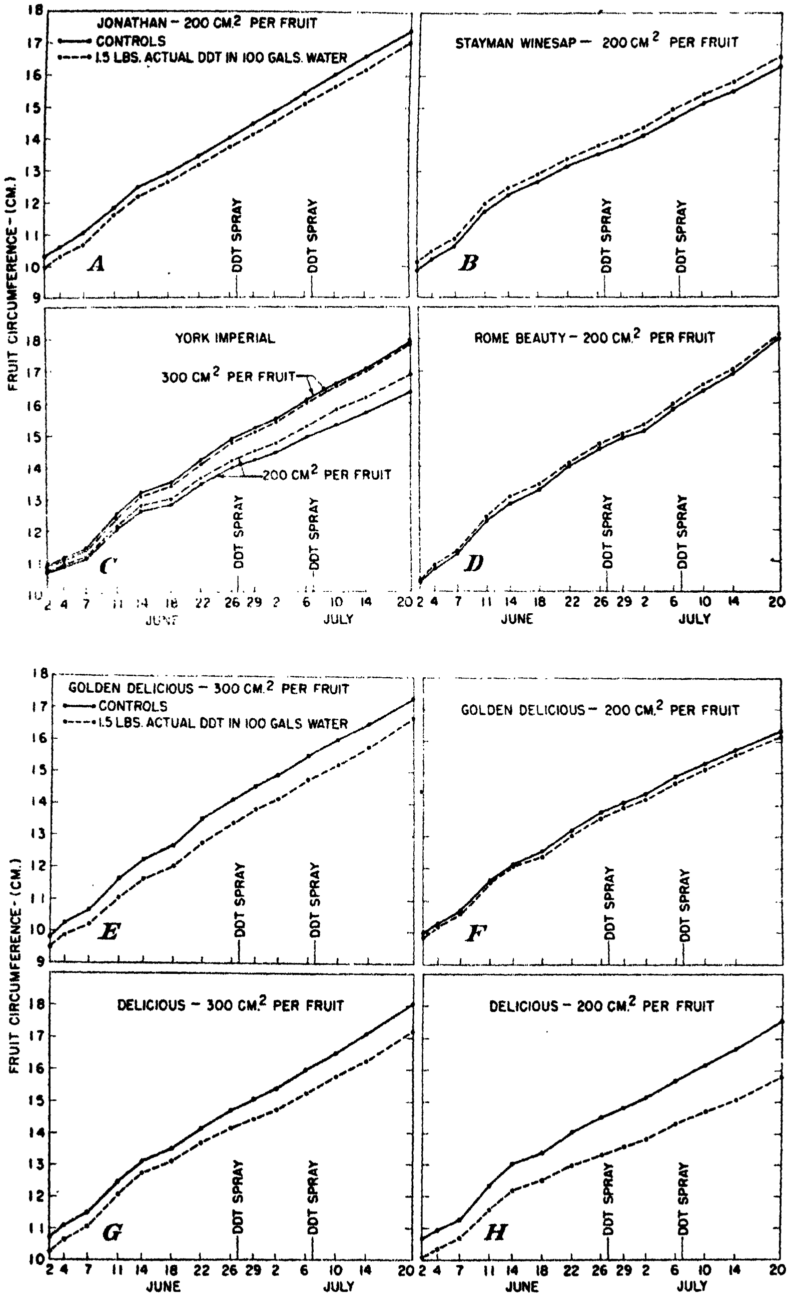

FIG. 1. Average growth rate of apples on DDT-sprayed and unsprayed bark-girdled branches adjusted to 200 cm² and 300 cm² of leaf area per fruit.

DDT and the control curves after the DDT applications, it is evident that with the methods employed and under the conditions prevailing in the course of this study, leaf efficiency was not impaired by DDT residues on apple foliage. The fact that the apples on some limbs sprayed with DDT were smaller in both the 200- and 300-square-centimeter leaf-area groups is coincidental and due entirely to chance variation at the beginning of the experiment.

Maximum temperatures and precipitation occurring in the orchard are given in Table I. These data indicate that neither relatively high temperature nor rainfall altered the slope of the growth curves after sprays were applied.

The results obtained in this study are valid only as to sprays of the formulation described. DDT may not be innocuous to apple leaves if combined with certain materials sometimes used as orchard sprays (1).

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Little-Leaf or Rosette of Fruit Trees VIII: Zinc and Copper Deficiency in Corral Soils

By W. H. CHANDLER, *University of California, Los Angeles, Calif.*, D. R. HOAGLAND, and J. C. MARTIN, *University of California, Berkeley, Calif.*

IN California nearly all, if not all, soils on which trees show zinc-deficiency injury and some soils on which they show copper deficiency are able to supply to field crops and alfalfa enough zinc and copper for excellent growth. We have tried to learn why trees and vines are unable to obtain all the zinc and copper they need from some soils that supply enough to other plants.

Most of the soils on which trees normally show zinc deficiency in the San Joaquin Valley are sandy, but trees on sandy soils in coastal districts rarely show zinc deficiency. In old corral areas where animals were concentrated for a considerable number of years, trees may show both zinc and copper deficiency in coastal as well as interior districts, even if the soil is clayey and the area one in which zinc and copper deficiency are not found except in such old corral spots. These deficiencies may be shown even if the spot ceased to be used as a corral 30 years ago, or longer.

In the parts of such an area most used by animals, trees may show these deficiencies during their first or second year in the orchard, may even die by the end of the second year or sooner, while in parts less used by the animals, trees may make good growth in their first 2 or 3 years and show injury only in their third or fourth year, as they do on non-corral sandy soils in interior districts. In one corral spot, treatment with zinc alone kept the trees healthy, but in all others that we studied, treatment with zinc alone in winter would keep them apparently healthy until about midsummer when copper deficiency symptoms showed as browning of the leaves at the tips and shedding of many leaves. Treatment with zinc and copper usually cures all symptoms, but in part of one old corral area, magnesium also was required. In part of this corral spot and in another area that had just ceased to be used as a corral and had not been so used long, the injury was not due to zinc or copper deficiency, but seemed to be due to salt. Special accumulations in old corral soils seem to be largely of potassium bicarbonate and phosphorus and nitrogen compounds. In the part that was most intensely used by the animals, the soil reaction may be alkaline enough to cause injury to annual plants and alfalfa as well as to trees, but in most old corral soil, annual plants tend to be exceptionally vigorous, partly because of the high nitrogen. The high potassium tends to reduce the availability of magnesium to such an extent that little or none is extracted with water, but trees have shown a measurable response to applications of magnesium in only this one small area.

Trees of a species that can retain enough zinc from a dormant spray with a zinc compound seem to respond as well when growing in a corral spot as elsewhere, and galvanized iron pieces driven into the

trunk or branches seem to be as effective in corral trees as in others. For soil treatments to be effective, more zinc sulphate and copper sulphate had to be used in old corral spots than would be required to cure deficient trees in most other soils. We could not determine whether this high fixing power was due to the manure residues in the soils or whether these spots happened to be on soils with exceptionally high fixing powers for zinc and copper.

In one corral spot, alfalfa was planted to see if it would slowly cure zinc deficiency in such a soil as it does in some others, and to see if it would cure also copper deficiency. Both zinc- and copper-deficiency symptoms disappeared after three years in a strong alfalfa sod. On some of these trees, but not on all, symptoms of both zinc and copper deficiency reappeared in the third year after the alfalfa was plowed under; too many trees remained free from deficiency symptoms, however, for the evidence to be more than suggestive that the improvement was all due to the alfalfa and that alfalfa sod can increase absorption of copper as well as zinc by trees.

Attempts to Produce Corral Effects

If we could learn how long-continued use of a soil in a corral causes its zinc to be less available to trees, we might obtain leads for study of the cause of zinc deficiency in trees on other soils that supply enough to annual plants and alfalfa. Because trees showing slight zinc-deficiency symptoms when the nitrogen supply is low will show much more striking symptoms when forced into rapid spring growth by heavy nitrogen applications, treatments at first were given to learn the effects of as great an excess of nitrogen as a corral soil has. Besides the treatments in Table I, different plats received urea, ammonium nitrate, or ammonium sulphate, each enough to supply as much nitrogen as the manure or the ammonium phosphate supplied. The trials began in 1933. The potassium carbonate plats were established later after experience had suggested that the manure salts might be more important than nitrogen in causing the zinc deficiency. If very heavy applications of manure should cause zinc deficiency and applications of as much or more potassium carbonate and phosphate in mineral form should not, then we might conclude that manure residues produce zinc deficiency by some other influences than locking it up in highly insoluble carbonates and phosphates.

Treatments were discontinued in 1937. Some of the amounts of the substances indicated in Table I were given in six equal applications, some in five, some in four, the potassium carbonate was in two applications. Observations continued through the summer of 1945.

In Table I are shown the effects of these treatments on the amounts of potassium, phosphorus and bicarbonate in a 1 to 1 water extract from the soil by 1939, and the amounts of the same substances in such an extract from several corral soils.

The San Jose soil was a Yolo clay loam newly planted to Lovell peach and Royal apricot trees. No trees in the neighborhood showed zinc deficiency and none of these showed any by the end of observations in 1945, or any other injury except a considerable dwarfing by

TABLE I—PARTS PER MILLION OF CERTAIN IONS IN DRY SOIL: CORRAL SOILS AND TREATED SOILS

Treatments	Inches	pH	K	HCO_3	PO_4
Peach and Apricot Trees, San Jose					
Check	6-12	6.3	5.0	96	3.9
Check	14-24	6.6	8.6	84	2.3
Urea, 11,520 pounds + K_2CO_3, 28,000 pounds per acre	6-12	8.8	239.0	584	9.4
Urea, 11,520 pounds + K_2CO_3, 28,000 pounds per acre	14-24	8.6	134.0	244	2.3
Ammonium phosphate, 26,400 pounds per acre	6-12	4.3	3.4	72	31.0
Ammonium phosphate, 26,400 pounds per acre	14-24	4.6	3.6	72	17.0
Manure, 768,000 pounds per acre	6-12	7.1	7.2	268	19.0
Manure, 768,000 pounds per acre	14-24	7.1	3.2	193	6.8
Peach Trees, Chester Sackel, Winters					
Super phosphate and nitrogen = ammophos, 8,000 pounds and super phosphate, 8,000 pounds per acre	6-12	6.8	5.0	158	91.0
Super phosphate and nitrogen = ammophos, 8,000 pounds and super phosphate, 8,000 pounds per acre	14-24	7.1	5.6	134	67.0
Manure, 480,000 pounds per acre	6-12	7.2	29.0	96	15.6
Manure, 480,000 pounds per acre	14-24	7.1	11.0	146	6.0
Check	6-12	8.2	5.3	220	3.0
Check	14-24	7.8	2.2	122	1.3
K_2CO_3, 16,000 pounds per acre	6-12	—	30.1	—	—
K_2CO_3, 16,000 pounds per acre	14-24	—	5.8	—	—
Adjacent Corral Area	6-12	6.5	23.0	80	10.9
Adjacent Corral Area	18-24	6.5	29.0	55	6.6
Grape Vines, E. C. Ruehl, Delhi					
Manure, 480,000 pounds per acre	6-12	5.8	6.0	25	3.8
Manure, 480,000 pounds per acre	18-24	6.5	8.0	39	2.7
K_2CO_3, 16,000 pounds per acre	6-12	6.9	6.0	35	1.5
K_2CO_3, 16,000 pounds per acre	18-24	6.9	4.0	50	1.2
Ammonium phosphate, 15,000 pounds per acre	6-12	6.3	7.0	32	9.1
Ammonium phosphate, 15,000 pounds per acre	18-24	4.0	10.0	00	19.4
Check	6-12	6.9	5.5	57	0.9
Check	18-24	6.6	5.0	42	1.0
Walnut Planting, Walker, San Jose					
Outside corral area	6-12	7.2	7.6	134	7.6
Outside corral area	14-24	7.4	6.1	108	8.0
Bad corral area	6-12	7.4	14.0	158	16.0
Bad corral area	14-24	7.5	11.0	134	17.0
Bad corral area	6-12	7.6	39.0	292	33.0
Bad corral area	14-24	7.6	32.0	194	30.0
Apple and Stone Fruit Trees, Leighton Turlock					
Outside corral area	6-12	6.5	5.4	183	4.8
Outside corral area	14-24	6.4	3.5	108	3.8
Corral: Alfalfa injured	6-12	8.8	163.0	268	58.0
Corral: Alfalfa injured	14-24	9.1	95.0	170	60.0
Corral: Trees injured, alfalfa healthy	6-12	8.8	92.0	170	35.0
Corral: Trees injured, alfalfa healthy	14-24	7.5	29.0	146	32.0
Corral: Trees injured, alfalfa healthy	6-12	7.3	36.0	158	34.0
Corral: Trees injured, alfalfa healthy	14-24	8.9	83.0	158	41.0

the calcium nitrate until several years after the treatments were discontinued and possibly a slight dwarfing by the ammonium phosphate. Even the succulent growth following a very severe dormant pruning showed no evidence of zinc deficiency. Thinking that such substances in urine as indican and creatine might form compounds with zinc or copper that are more insoluble than zinc carbonate or zinc phosphate and that part of the urine may have been leached out of the manure before it was applied, two trees in the urea plot were treated annually from 1941 to 1945 with washings from a dairy barn that contained about 10 per cent of urine. Probably during the 5 years 100,000 gallons of urine per acre was applied. The foliage became very dark green but showed no evidence of zinc or copper deficiency, or any other injury.

The Chester Sacket peach orchard near Winters was in an Esparta clay loam. A short distance from the treated trees in an old hot-bed area, peach trees showed fairly serious zinc deficiency symptoms, and in a corral spot across a narrow road from the treated trees, rather serious zinc deficiency was shown by peach trees. In the winter of 1936–37, the trees in the block that included the treatments were top-worked low on the main branches. In the spring practically all the young succulent shoots, except those on branches that had zinc pieces driven into them, showed rather striking zinc deficiency symptoms; but the leaves that opened later in summer were normal. And in succeeding years to 1945, no trees in treated or check plots showed any evidence of zinc or copper deficiency. In other words, heavy manuring and heavy applications of mineral nitrogen, of potassium carbonate, or of phosphate, failed to cause peach trees to show zinc deficiency on this soil, that was not near to being injuriously deficient that trees in it showed serious deficiency as a result of soil use in a corral or in hot beds, and fairly striking temporary deficiency as a result of severe pruning.

The Ruehl soil is a blow-sand in the Delhi area and was planted to Zinfandel grapes. Samples for these analyses were taken in 1945; there had been 7 years longer for leaching out material applied than in the San Jose and the Sackett soils. Nearly every peach tree in the row adjacent to these grapes had shown zinc deficiency. None of the treatments shown in the table or any other nitrogen treatments caused any deficiency symptoms or other injury to the vines or to the peach trees that followed them, although the ammonium phosphate and, to a less extent, the calcium nitrate, were toxic enough at the surface to impede for several years the growth of weeds on the areas covered.

The land in the Walker corral area was a gravelly clay loam. Part of it was in a chicken run from about 1905 to 1920, part in a feed lot for hogs from about 1905 to 1910, and part in a horse corral from about 1865 to 1910. Walnut trees and, earlier, prune trees showing zinc and copper deficiency were in all three areas. Apparently the worst was in those spots, such as along the fences, that were used by the animals most. The soil samples were taken from near trees that showed very serious deficiency.

The soil in the Leighton corral was a rich sandy loam. It had been used as a horse corral, and possibly to some extent for a cattle corral, for an unknown number of years before 1908, when it was put into cultivation. Young trees of apple, pear, peach, plum, and walnut, were planted in 1935. In the salty part where the alfalfa was injured, most of the trees died in the first or second year without showing distinct zinc- or copper-deficiency symptoms, but in the part where annual plants grew well and alfalfa was later found to do so, the trees grew moderately well and showed distinct zinc- and copper-deficiency symptoms by the time they were 2 or 3 years old.

Discussion

Some of the treatments recorded in Table I which did not cause zinc or copper deficiency gave the soil as great ability to deliver phos-

phorus to water as had most of the corral soils on which trees showed very serious zinc and copper deficiency. This is in agreement with the report of Jamison (2) who did not find phosphorus fertilizers to reduce the availability of zinc or copper in several sandy soils in Florida. Excess of carbonates in these treatments also failed to cause zinc or copper deficiency, as did a very great excess of nitrogen. Apparently when application of nitrogen seems to cause zinc deficiency, it does so by causing, on trees already deficient in zinc, the growth of long, succulent shoots that show zinc-deficiency symptoms most clearly.

If water-soluble manure salts can be depended upon as a measure of the amount of manure a soil has received, the amounts applied in these treatments that failed to cause zinc or copper deficiency were greater than the animals had applied to some of the corral spots on which trees show very serious zinc and copper deficiency. Apparently no substance in the manure caused zinc or copper deficiency by merely forming insoluble combinations. The animals must have had some other effect on the soil. Possibly the trampling and puddling together with the abundance of organic matter and potassium may have caused the zinc and copper ions to be more inaccessible within the colloidal particles. On the other hand, this puddling, or the long-continued application of fresh urine and other organic, nitrogenous compounds, may possibly have changed the soil flora in a way that reduced the amount of zinc and copper available to trees, as suggested by Hoagland (1) for other soils. We have obtained from this study no help toward an understanding of why trees are sometimes unable to obtain zinc enough from a soil that supplies enough to annual plants and alfalfa.

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The Influence of Various Fertilizers and Foliage Sprays on the Internal Structure of Apple Leaves[1]

By WM. F. PICKETT and J. C. BATES, *Kansas Agricultural Experiment Station, Manhattan, Kans.*

A REVIEW of the literature and various studies on the influence of spray materials on the internal structure and chlorophyll content of apple leaves have been reported by Pickett and Birkeland (1). These investigators made use of a formula developed by Turrell (2) to determine the ratio (R) of the internal exposed surface to the external surface of apple leaves of different varieties from different locations and subjected to different foliage spray treatments. They obtained a high coefficient of correlation (+0.88) between the R value obtained by Turrell's formula and the total depth of palisade tissue in microns (P) and developed the formula $R = 0.1122\ P + 1.33$.

Pickett and Birkeland found that some spray materials reduce the R value of apple leaves. They also cited other research work indicating that some spray materials reduce the photosynthetic activity of foliage leaves, and concluded that the R value of apple leaves is one of the factors influencing the rate of photosynthetic activity.

Pickett and Kenworthy (3) determined the ratio between the increase in dry weight of young York, Jonathan and Wealthy apple trees per square meter of leaf area and the R value of the leaves, and obtained a coefficient of correlation of +.70 between the two values. Thus, the R value of the leaf, in addition to its value in showing the shrinking or expanding effect of different treatments on the mesophyll cells, may be used as an index of photosynthetic activity.

In view of the previous work, it seemed desirable that some studies be made on the influence of some of the new insecticides and fungicides, commercial fertilizers, and various combinations of fertilizer and insecticides or fungicides on the structure and photosynthetic activity of apple leaves.

TREATMENTS AND RESULTS

The influence of Gesarol AK 20 (Dichloro-diphenyl-trichlorethane, DDT) foliage spray applied at the rate of 2 pounds to 100 gallons of water on the R value of the leaves of 4-year old Winesap apple trees in the college orchard near Manhattan was determined in 1944.

Nine of the 18 trees used in the experiment were given 5 applications of the foliage spray between July 6, when the tagged leaves unrolled, and August 10; the other 9 trees served as checks. On September 15, 72 days after the tagged leaves had unrolled, the R value of 4 leaves of each of the 18 trees was determined. The average R values were 15.13 and 15.82 for the sprayed and unsprayed leaves respectively. Although the data showed that Gesarol AK 20 foliage spray decreased the R value of the leaves of Winesap apple trees growing in the orchard 0.69 below that of the untreated checks, the

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tree-to-tree variation was sufficiently large that the observed average difference of 0.69 is not statistically significant.

The influence of Gesarol A 20 foliage spray applied at the rate of 2 pounds to 100 gallons of water was compared with that of lead arsenate applied at the rate of 4 pounds to 100 gallons on the R value of the leaves of 30-year old Jonathan apple trees growing in the Blair experimental orchard, near Blair, Kansas, 1944.

Each of the above treatments was applied to two trees on the following dates: Calyx spray, May 25; first, second, third, fourth, and fifth cover sprays on May 30, June 6, 15, 26, and July 12 respectively.

The average R value of eight leaves taken from the southwest side of each tree on July 22 was determined. The average R value of the leaves treated with Gesarol A 20 and lead arsenate was 11.65 and 11.05 respectively.

The data were analyzed statistically by analysis of variance. The statistical probability of significance for the treatments Gesarol A 20 compared with lead arsenate approached fairly closely the 5 per cent level of significance and for all practical purposes could be called significant (F = 3.32; required F value with odds 19 to 1 is 3.87).

To determine the influence of different foliage sprays on the R value of the leaves of Jonathan apple trees, the following four treatments were applied to trees planted in the ground bed of a greenhouse on January 8, 1945.

1. Gesarol AK 20 spray applied at the rate of 4 pounds to 100 gallons of water.
2. Fermate foliage spray applied at the rate of 1.6 pounds to 100 gallons of water.
3. Lead arsenate foliage spray applied at the rate of 4 pounds to 100 gallons of water.
4. Untreated checks.

The treatments were applied on the following dates: February 17, 24; March 2, 9, 16, 23, 30; April 6, 13, 20, 27, and May 4. There were 12 replications of each treatment.

On May 7, the R value of 4 leaves from each tree was determined. These leaves had received 10 applications of foliage spray.

The average R value of the leaves of each treatment group was as follows: Untreated checks, 12.36; sprayed with Gesarol AK 20, 12.18; sprayed with lead arsenate, 12.12; and sprayed with Fermate, 11.88. The data showed that all three of the foliage sprays decreased the R value of the leaves below that of the untreated but only the difference obtained between the fermate treatment compared with the untreated checks approached the 5 per cent level of significance and for all practical purposes could be called significant (F — 4.18; P = .055 instead of the conventional P = .05).

To determine the influence of 0.5 per cent solutions of ammonium nitrate, sodium nitrate and urea foliage sprays on the R value of the leaves of 3-year old Wealthy, Winesap and Jonared apple trees at the College farm near Manhattan, each of three trees of each variety was sprayed with a different salt solution and a fourth unsprayed tree served as a check.

The sprays were applied on the following dates: June 30; July 2, 12, 20, 27 and August 3, 13, 23, 31, 1943.

The R value of leaves from these trees was determined on August 23 and on October 14, after receiving seven and nine applications of foliage spray respectively. The results are shown in Table I.

TABLE I—INFLUENCE OF NITROGENOUS FOLIAGE SPRAYS ON THE R VALUE OF THE LEAVES OF ORCHARD-GROWN APPLE TREES, 1943

Number of Spray Applications	Treatment	Average R Value
	Wealthy	
9	NH_4NO_3	16.85
9	$NaNO_3$	17.95
9	Urea	17.99
0	Checks	16.72
7	NH_4NO_3	18.29
7	$NaNO_3$	19.98
7	Urea	18.92
0	Checks	17.02
	Winesap	
7	NH_4NO_3	15.67
7	$NaNO_3$	17.27
7	Urea	17.57
0	Checks	14.63
	Jonared	
9	NH_4NO_3	15.33
9	$NaNO_3$	13.97
9	Urea	14.18
0	Checks	12.25

The data in Table I show that spraying the foliage of Wealthy, Winesap and Jonared apple trees with 0.5 per cent solutions of NH_4NO_3, $NaNO_3$ and Urea increased the R value of the leaves above that of the untreated checks. Urea and $NaNO_3$ have about equal influence but compared with these, the NH_4NO_3 has less influence on Wealthy and Winesap and greater influence on Jonared.

The difference in R values between the check leaves and treated leaves is statistically significant ($P = .009$), whereas the differences among the treatments are well within the bounds of sampling variation.

To determine the influence of various fertilizer and foliage spray treatments on the R value of the leaves of Winesap apple trees, the following 10 treatments were applied in 1944, to trees which were planted in the spring of 1943 at the college farm near Manhattan.

1. Untreated checks.
2. Curbay fertilizer (5–10–5) applied at the rate of 48 ounces per tree in an area 6 feet in diameter (1000 pounds per acre.)
3. Ammonium sulphate applied at the rate of 12 ounces per tree in an area 6 feet in diameter (250 pounds per acre).
4. Uramon (urea) foliage spray applied at the rate of 5 pounds to 100 gallons of water.
5. Sulphur foliage spray consisting of 8 applications of wettable sulfur-lead arsenate applied at the rate of 5.5–2.0 pounds per 100 gallons of water.

6. Fermate foliage spray consisting of Fermate, hydrated lime and lead arsenate applied at the rate of 1.6–1.6–3.2 to 100 (pounds to 100 gallons).
7. Both treatments 3 and 5.
8. Both treatments 3 and 6.
9. Both treatments 4 and 5.
10. Both treatments 4 and 6.

The ammonium sulphate and Curbay fertilizers were applied on May 23.

The foliage sprays were applied on the following dates: June 2, 8, 15, 22, 29, and July 6, 13, 20 and 27.

All of the trees had received one application of lead arsenate foliage spray for cankerworm control a few days before the experiment was begun.

The influence of the different treatments on the R value of the leaves is shown in Table II in which the average R value for each treatment was obtained from five replications, eight leaves per replica and 20 measurements per leaf.

The sprayed leaves used for R value determinations had received 9 applications of foliage spray.

TABLE II—INFLUENCE OF DIFFERENT SOIL FERTILIZER AND FOLIAGE SPRAY TREATMENT ON THE R VALUE OF ORCHARD-GROWN WINESAP FOLIAGE. 1944.

Treatment	R Value
Untreated checks	16.85
Curbay soil treatment	17.34
Ammonium sulfate soil treatment	17.32
Uramon spray	17.29
Wettable sulfur lead arsenate spray	17.03
Fermate–lime–lead arsenate spray	16.78
Ammonium sulfate soil treatment and wettable sulfur–lead arsenate spray	17.81
Ammonium sulfate soil treatment and Fermate–lime–lead arsenate spray	17.47
Uramon wettable sulfur–lead arsenate spray	17.31
Uramon–Fermate–lime–lead arsenate spray	16.90

An analysis of variance for R values shows that the variance between all treated and untreated foliage was not significantly greater than the variance between trees except the R value of treatment No. 7 were highly significantly greater than No. 1. The difference between treatments No. 5 and No. 7 was significant at the 5 per cent level.

SUMMARY

1. Gesarol AK 20, 2 pounds per 100 gallons of water reduced the R value of foliage on 4-year old Winesap apple trees when compared with unsprayed foliage.

2. The R value of the foliage of 30-year old Jonathan apple trees sprayed with lead arsenate diluted at the rate of 4 pounds per 100 gallons of water was 11.05. The R value of the foliage sprayed with Gesarol A 20, 2 pounds per 100 gallons of water, was 11.65. The difference between these values was fairly close to the 5 per cent level of significance.

3. The foliage of young Wealthy, Winesap and Jonared trees which had been sprayed with nitrogenous fertilizers had higher R values than untreated foliage. The differences were significant.

4. The R value of foliage from trees sprayed with wettable sulfur-lead arsenate and fertilized with ammonium sulfate was highly significantly greater than the R value of untreated foliage. A significant difference was found between the R values of foliage which had been sprayed with wettable sulfur-lead arsenate and foliage from trees sprayed with this combination and fertilized with ammonium sulfate. This would suggest the desirability of using quickly available nitrogenous fertilizers in those orchards which receive several applications of wettable sulfur-lead arsenate sprays.

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Little-Leaf or Rosette of Fruit Trees IX: Attempt to Produce Corral Injury with Constituents of Urine

By W. H. Chandler and David Appleman, *University of California, Los Angeles, Calif.*

Two constituents of animal urine (creatine and indican) form highly insoluble compounds with heavy metals. To learn whether or not these may be part or all of the cause of zinc and copper deficiency to trees in corral soils, Santa Rosa plum trees were planted in 5 gallon cans heavily coated inside with asphalt and containing potting soil treated with one or the other of these or related compounds. Soil treated with succinic acid was also used because under some conditions it seems to be formed in soils and may possibly cause deficiency of heavy metals. Five trees received each treatment and five were checks. Creatine was not always available and creatinine was used in most of the applications, the assumption being that either of these would have the same effect in the soil. Indican was not available, indigotin was used instead. In the first treatment (when the trees were planted February 12, 1943) 5 grams of indigotin was mixed with the soil for each of the 5 trees, in succeeding treatments it was worked into the surface soil. The other substances, being more soluble, were dissolved in distilled water and poured on the surface. The soil was exposed to rains in winter, but all other waterings were with distilled water. The amounts and dates of treatments were as follows:

Dates	Creatinine (Grams)	Indigotin (Grams)	Succinic Acid (Grams)
February 12, 1942	2.5	5.0	5.0
May 6, 1943	2.5	5.0	5.0
February 9, 1944	2.5	5.0	5.0
June 30, 1944	5.0	10.0	10.0
December 5, 1944	10.0	20.0	10.0

Trees were all discarded in August, 1945. All were pruned rather severely in the Springs of 1944 and 1945 to accentuate zinc deficiency symptoms if any should appear. No symptoms of any kind were shown until the Summer of 1945, except that the nitrogen in the creatinine caused stronger growth and deeper green foliage. The same was true to a much less extent of the indigotin. In the Spring of 1944 all trees received potassium nitrate and ammonium phosphate; the creatinine trees about one-fourth as much as the others; the indigotin trees about nine-tenths as much. In June, 1944 and in February, 1945 they were fertilized again. In the Summer of 1944 the creatinine trees still looked greener and grew more vigorously than the others.

In the Spring of 1945 two of the creatinine trees were nearly dead and in the summer the three remaining showed some leaf injury; apparently the last application had caused toxic concentration of the compound. No tree in any treatment showed evidence of zinc or copper deficiency. These substances must have been as concentrated in this soil as they would be in a corral or much more so. The evidence suggests that none of them can be the cause of unavailability of zinc or copper to trees in corral soils.

Foliar Diagnosis: Boron in Relation to the Major Element in Apple Trees[1]

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INTRODUCTION

IN 1943 a severe infestation by *B. amylovorus* (fire blight organism) occurred in the College experimental orchard No. 3 planted in 1935 to Rome apple trees on Malling type II stock. Of the 60 trees in this orchard one, however, was found to be completely disease-free; the others showed varying degrees of infection, but all could be designated severe. Some of the trees in orchard No. 1 also had some blight that year. These were older trees planted in 1907 and were of the York variety. The degree of infection was relatively light in these Yorks.

Symptoms which have been described as evidences of boron deficiency were observed during winter storage of the 1943 fruits from these orchards, though it was not known from which trees these fruits were harvested: in the Yorks, internal lesions characteristic of so-called corky core were apparent, and in the Romes, premature ripening occurred in many fruits, which is considered an evidence of mild deficiency of boron.

Although the Romes have received the same annual application of fertilizers and identical systems of cultivation (see Table I), large differences were found in the content of certain elements in leaves of the same type and age collected in July and August 1943 from the disease-free tree and that of an adjacent tree which was the most severely blighted in this orchard. These differences in composition held throughout the cycle, and were greater than that known to exist between differentially fertilized trees of one variety (Yorks) and also among similarly fertilized trees of different varieties such as Rome, Delicious, and Stayman growing in adjacent experimental orchards of the College, comparisons being made at the same physiological periods. For reasons which will become apparent later, determinations of boron also were made. It was found that the content of this element in leaves of the diseased tree, B38, in 1943 was lower throughout the cycle than in those of the same type and age of the disease-free tree, D31.

Blight and boron deficiency have not been associated. The first effect of boron deficiency is the interruption of cell formation and cell differentiation. In general the characteristic leaf markings common to most species are absent in apple trees (3). Such symptoms as yellowing of the apical margins and its extension between the lateral veins and mid-veins of the leaves, or brittleness and tendency to curl, or both; also degeneration diseases of the fruit make their appearance only when the available supply of boron is considerably below that required for best growth. But the question of sufficiency of boron

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in apple trees remains open, as also do the qualitative and quantitative relationships to the major elements.

This paper reports data for the two Romes already mentioned and, in addition, also for the York trees of an accompanying paper. This investigation, accordingly, was initiated in an attempt to learn what (if any) nutritional conditions were associated with blight; but developed in the absence a satisfactory answer on this point, into a search for indices of boron deficiencies or sufficiencies.

Experimental

The Soil:—The ultimate analysis of the soil, a Hagerstown silty clay loam, upon which these trees are grown has been reported (11). The following quantities of boron were found by the methyl ester method, which is less convenient than the quinalizarin method, particularly for quantities of boron less than 0.004 mgm per ml. In terms of the dry soil the values found were: surface—Total boron 60 ppm; subsurface—65 ppm; extracted with O.1N HNO_3; surface—2.50 ppm; subsurface—2.75 ppm. Boron is present in this soil as tourmaline which has been identified in both sand and silt fractions, and in relatively greater quantities in the latter. On the basis of these results it has hitherto been assumed that the boron content of the soil of the College farm is sufficient for the crops grown.

Sampling:—In the present work leaf samples were taken from the middle of non-bearing terminal shoots: from the Romes on July 7, July 28 and August 18 in 1943 and on June 17, July 5, July 27 and August 14 in 1944 and on the same dates from the Yorks, with the addition of a June 18 sampling in 1943.

Presentation of Data:—Table I gives, for the Romes, the tree numbers, fertilizer tretments up to 1943, together with the changes in treatment made in 1944, and the yields for the two years. Similar data for the Yorks are recorded in an accompanying paper.

Figs. 1 and 2 present for 1943 and 1944 the analytical data (as percentages in the dried foliage) for the content of morphologically homologous leaves, namely, from the median portion of the seasonal shoot growth, with respect to nitrogen, phosphoric acid, potash, lime, magnesia, and boron. In accordance with our practice the data are expressed, for the major elements, in terms of the International units, and for boron as the element (12).

Figs. 3 and 4 present for 1943 and 1944, respectively, the qualita-

TABLE I—The Romes: Fertilizer Treatments Until 1943 and Changes Made in 1944

Tree No.	Fertilizer Treatment		Yield (Bushels)		Cultivation System
	1943	1944	1943	1944	
B38 (blighted)	3 pounds 10–6–4 annually up to 1942 4–12–4 in 1943	3 pounds 10–6–4 + 5 pounds $NaNO_3$ 2 pounds Borax	1.3	3.5	Mixed legume and non-legume cover, cultivated usually in the spring
D31 (healthy)	Same as B38	3 pounds 10–6–4 + 5 pounds K_2SO_4	0.6	2.1	Same as in B38

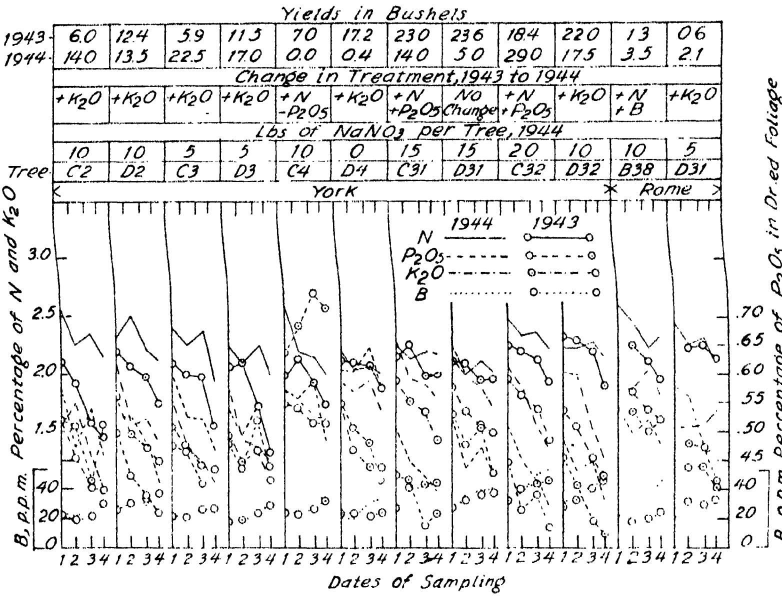

FIG. 1. The course of nutrition with respect to nitrogen, phosphoric acid, potash and boron in 1943 and 1944. *Ordinates:* percentages in terms of the dried foliage. *Abscissae:* Sampling periods.

tive relationships as represented by the values of boron with respect to the *NPK-units,* that is, the resultant NPK-equilibrium during the growth cycle of each of the trees (12). The boron values are given in parts per million of the dried foliage and represent the mean or resultant values for the growth cycle of the individual trees in 1943 (Fig. 3) and 1944 (Fig. 4).

Discussion and Interpretation

The loci representing the content of each element in the leaf at the moment of sampling in Figs. 1 and 2 indicate by their position the relative supply to the leaf of that element to the demand for it. The lines joining these loci, consequently, show by the degree of slope the variation in these relations during the cycle, a steep downward slope indicating great demand relative to supply, and a turn upwards, accumulation.

Characteristics of Nutrition:—In the Romes the significant features in 1943 are the much higher content of the leaves in potash and phosphoric acid, and the lower nitrogen, lime, magnesia and boron in tree B38; and the very low potash content of the leaves in tree D31 without, however, any symptoms of potash deficiency being present.

The nitrogen content of the blighted tree diminishes more rapidly than that of the healthy tree, although at the first sampling (July 7) the content of this element in the two trees differs little. At this sampling differences in moisture content do not indicate that this factor operated by its effect on the stomata and guard cells in determining

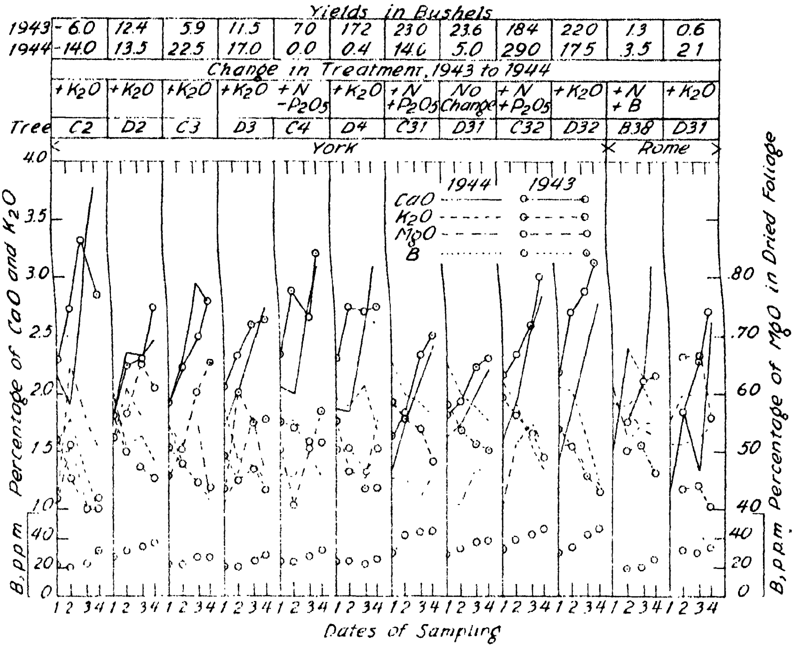

FIG. 2. The course of nutrition with respect to lime, magnesia, potash and boron in 1943 and 1944. *Ordinates:* percentages in terms of the dried foliage. *Abscissae:* Sampling periods.

invasion by the bacteria in one case and not in the other. At this date the values for imbibitional and total water for B38 were 54.1 per cent and 63.0 per cent respectively and for D31, 53.9 per cent and 63.2 per cent.

The principal characteristics of nutrition with respect to nitrogen, phosphoric acid, and potash in the Yorks for each year have been described in an accompanying paper. It remains only to point out that boron is much higher in the more vigorous trees C31, D31, C32, and D32 than in the less vigorous trees (C2, D2, C3, D3, C4, D4).

The addition in 1944 of 5 pounds extra $NaNO_3$ to tree B38 is associated with a content of nitrogen higher than in the previous year, with accumulation of this element in the latter part of the cycle. The addition of 2 pounds of borax to this tree (B38) in 1944 has brought about a marked increase in this element, which rises rapidly with maturity of the leaves. Also the addition of 5 pounds extra of K_2SO_4 to tree D31 in 1944 is accompanied by a much higher content of potash; but it has not reached the level of that of B38. Lack of utilization of potash towards the latter part of the cycle in this tree is indicated by accumulation at a relatively low level.

Course of Boron Nutrition:—In all trees the direction of the graphs for boron during the greater part of the cycle each year is inverse to those of nitrogen, phosphoric acid, and potash, reflecting increase in boron content with maturity of the leaf and decrease of the major

fertilizer elements. This is in accord with the findings of others (5, 8). The behavior of boron, therefore, in this respect is similar to that of calcium. The view has been expressed by McLean (8) that part of the boron may be stored in the leaf in a relatively unavailable form and this appears to hold for citrus (4); but Wolf (14) concludes from his work with cauliflower that boron is rapidly immobilized in the stems and leaves. The divergent views are related in all probability to the degree with which the differentiation of conducting tissue is affected, which in turn influences translocation, and thus alters the proportions of water-soluble and water-insoluble boron in the leaves.

The Calcium-Boron Ratio:—Physiologists have given attention to the relation of boron to the other elements, and evidence is accumulating that one of the functions of boron may be as a regulator of the permeability of plasma membranes. The existence of functional relationships between water-soluble boron and water-soluble potassium and also water-soluble calcium have been reported by Smith (10), Shive *et al*., (7, 9), whereas others (4, 14) have been unable to find such relationships.

The determination of water-soluble constituents of the fresh tissues is not within the province of the type of investigations designated and defined under foliar diagnosis (12). Jones and Scarseth (6) have sought simplification by considering the ratio of total calcium to total boron in the dried foliage as an index of deficiency or excess of the latter. This ratio has been calculated for the trees examined in this experiment. The ratios are recorded for the two Romes in Table II and for the Yorks in Table III.

TABLE II—THE CALCIUM-BORON RATIOS IN THE LEAVES OF ROME APPLE TREES

Date	Tree B38		Tree D31	
	1943	1944	1943	1944
Jun 16–18	—	491	—	364
Jul 5–7	687	633	406	485
Jul 27–28	731	411	531	365
Aug 14–18	607	470	576	584

Setting aside the question as to whether or not any functional relationship could be indicated by the ratio of the total quantities of the elements present in the leaf at corresponding periods, and examining the data solely from the point of view of their use as indices, it is to be noted that the Ca/B ratios are not constant with increasing maturity of the leaf in either year, as would be the case if the rates of increase of each element are equal throughout the cycle.

Jones and Scarseth (6) find for crops sensitive to boron deficiency a Ca/B ratio of 600, above which a deficiency of this element is indicated. Although apple trees were not investigated by them, this species belongs to the group highly sensitive to boron deficiency; this value of 600 may, therefore, tentatively be taken as applicable to this species. Of the two Rome trees this limit is exceeded at all periods in

the leaves of tree B38 in 1943 and on the first July sampling in 1944, and approaches this limit in tree D31 at the August sampling, in both years. There is, however, considerable variation in the values at different stages during the growth cycle: a fact which adds to the difficulty not only of applying the Ca/B concept, but also in deciding, when the boron values themselves are taken as in index, at what stage of growth the critical limit is to be set. The critical values, based on the percentage of boron in the dried foliage of apple trees, found by many workers (1, 5, 13, 15) vary between 9 and 12 parts per million (*circa* 10 ppm, say), but De Long (2) gives a critical value of 27 parts per million. It is not always stated what type and age of leaf is considered; but, presumably, when the age is not given the value is for the mature leaves. Askew and Chittenden (1) state that the "normal" value for boron in healthy leaves of apple trees is 25 ppm (dried foliage), although in some of their experiments trees having a leaf boron content of 18 ppm (dried foliage) were healthy.

The designation "mature leaf" is unsatisfactory, for in our experiment in some trees a large difference exists in the boron content of the first July sampling and the August sampling. De Long's limiting value (2) is for "spur leaves" of apple trees at picking time. For the leaves from spurs bearing affected fruit he found a boron content of 27 ppm and from unaffected ones 38 ppm.

The calcium-boron ratios for the York apple trees are given in Table III.

TABLE III—CALCIUM-BORON RATIOS IN THE LEAVES OF YORK APPLE TREES

Date	C2		D2		C3		D3		C4	
	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944
Jun 16 18	681	600	474	434	864	648	725	666	651	617
Jul 5-7	980	578	508	466	752	648	835	564	896	655
Jul 27 28	1,053	720	482	537	717	774	783	652	704	576
Aug 14 18	688	903	522	476	740	750	648	700	681	617

	D4		C31		D31		C32		D32	
	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944
Jun 16–18	675	609	412	339	457	384	478	321	515	312
Jul 5–7	821	562	318	362	415	335	420	359	576	391
Jul 27–28	881	567	390	362	442	360	438	400	493	359
Aug 14–18	768	647	387	400	431	372	465	409	479	334

As with the Romes the Ca/B ratios are not constant with increasing maturity of the leaf, indicating that the rates of increase of the two elements are not equal throughout the cycle. Five of the Yorks, namely, trees C2, C3, D3, C4, D4 are well above the value of 600 in 1943 (the range is 648 to 1053) and although the values are reduced in the following year at most stages of growth they are above 600. The percentage contents of boron in the leaves of these Yorks, however, are above the minimum recorded values for this species excepting that recorded by De Long (2) in spur leaves at picking time.

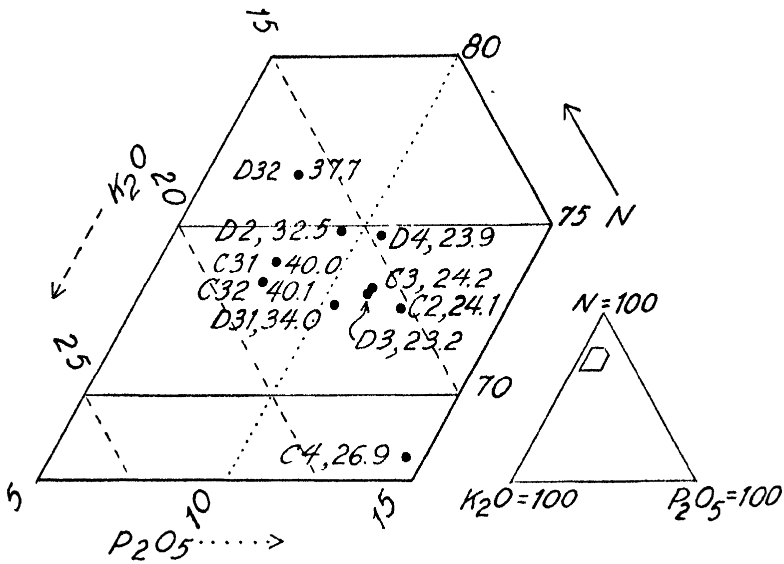

FIG. 3. Boron in relation to the loci of the *NPK-units* of the Yorks in 1943.

The Ca/B values for the most vigorous trees C31, C32, D31, and D32 are relatively low, especially in 1944, reflecting the relatively high boron content of the leaves of these trees.

There is no evidence in 1944 that any of the Yorks suffered from boron deficiency symptoms. In this species, therefore, the Ca/B critical value on the basis of the data of Table III would be 900 or higher. With such a critical limit the Ca/B values for the Rome tree B38, for which the percentage values in 1943 are relatively low, lose all significance. As an index, therefore, the Ca/B value in this species has no greater and probably less value than the percentages of boron themselves.

Boron in Relation to the Fertilizer Elements:—If, as many physiologists conclude, boron plays a direct rôle in protein synthesis, this element should be related to all factors affecting the growth of plants. It may be of interest, therefore, to examine the relationships of boron to those elements[2] used in practical agriculture to control the growth of crops. Logically, the relationship should be sought in terms of the effect factor of all the major elements acting collectively. A simple method of ascertaining this is by means of the graphic representation of the loci of the resultant *NPK-units* during the cycle (12). Figs. 3 and 4 show respectively the boron values for 1943 and 1944 in relation to these loci.

The resultant values for boron, that is, the values when all periods are taken into consideration, satisfies the following condition:—

[2]Ratios of N/B, P/B, and K/B have been calculated at each date of sampling for all trees. Their value as indices is as questionable as that of the Ca/B ratios. Anyone desiring copies of the complete tables can secure them from the authors.

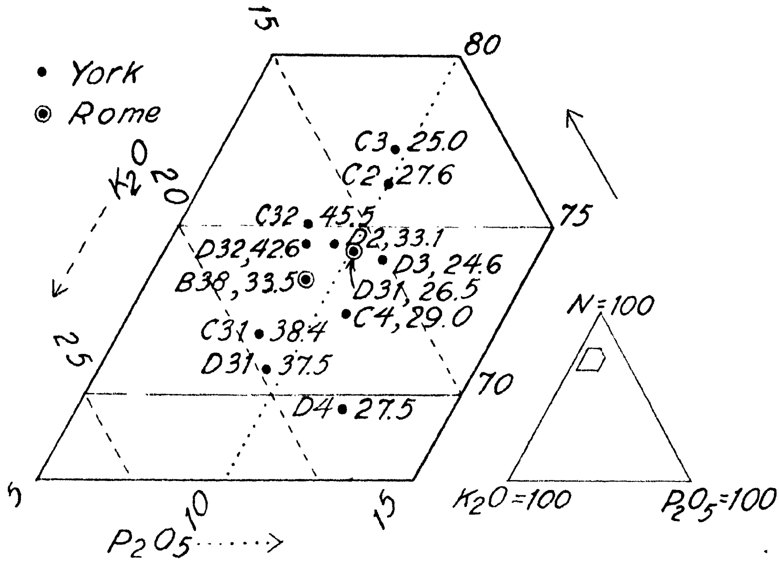

FIG. 4. Boron in relation to the loci of the *NPK-units* of the Yorks and Romes in 1944.

Boron *decreases* as the values for nitrogen, phosphoric acid, and potash respectively in the unit *increase* and conversely.

The effect factor of phosphoric acid is greater than that of nitrogen and potash combined; and that of nitrogen is greater than that of potash. The influence of the latter is small. These facts may explain the inconsistent results reported on the effect of certain fertilizers, particularly of potash, on the boron content (or boron deficiency symptoms) of plants.

The values of boron in relation to the *CaMgK-units* (not shown) are not consistent.

Boron and yields: The discussion and interpretation of this paper may seem incomplete without some reference to the important question of yields; but difficulties inherent in the problem of the relation of nutrition to yield are apparent from an accompanying paper. With respect to boron, the view has been expressed (8) that boron is withdrawn from the leaves by the developing auxiliary flowers and may be necessary before fruit can set. It is now apparent from all the work carried out on the role of boron that this element is not a nutrient in the ordinary sense but serves as an activator. Its relation to yields, therefore, must be indirect. No relationship is found between the boron values and yields, although, as already pointed out, the most vigorous trees have a high boron content.

SUMMARY AND CONCLUSIONS

In this paper, the nutrition of certain Rome and York apple trees in the experimental orchards of the Pennsylvania Agricultural Ex-

periment Station is examined by the method of foliar diagnosis, with respect to boron and its qualitative and quantitative relations to other nutrient elements and with respect also to varying degrees of infection by the fire blight organism *(Bacillus amylovorus)*, in order to discover satisfactory indices of boron deficiency or sufficiency. The trees had been grown, up to the time of these studies, under different systems of soil management and fertilization which resulted in wide differences in vigor and productiveness, on a soil which an ultimate analysis had led the investigators to assume would supply sufficient amounts of boron to meet the requirements of crops grown upon it.

It was not possible to discover in the data examined any consistent relation of the major nutrient elements to the severity of fire blight infection, or of boron concentration in the dried foliage to any one of the major nutrients as expressed in the ratio of the concentration of each of these elements to that of boron. A consistent relationship was found, however, between boron concentration and the balance of nutrition with respect to the fertilizer elements, as expressed in the resultant NPK-units. This relationship, which is fully described, suggests a means by which deficiency or sufficiency of boron can be ascertained, with respect to development and yield of crops.

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Effects of 2,4–Dichlorophenoxyacetic Acid Sprays in Controlling the Harvest Drop of Several Apple Varieties

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In experiments performed in 1944 on Winesap apples (1), 2,4–dichlorophenoxyacetic acid, while less effective in delaying fruit drop immediately following spray applications, was found to extend the effective period considerably beyond that usually obtained with napthaleneacetic acid. In order to obtain effectiveness with this compound, comparable to napthaleneacetic acid immediately following treatment, the authors suggested the possibilities that applications be made at an earlier date with reference to fruit maturity, and that the 2,4–dichlorophenoxyacetic acid be combined with Carbowax or napthaleneacetic acid or with both. The present work was designed to obtain information on these points and to further explore the possibilities of 2,4–dichlorophenoxyacetic acid in controlling the harvest drop of several varieties of apples.

Materials and Methods

All spray applications were made with standard portable spray equipment, and were applied with 500 pounds pressure using a single-nozzle gun. The limb unit method (four limbs per treatment) was used with Oldenburg (Duchess) and McIntosh. In the Delicious and Winesap experiments, treatments consisted of eight trees each, with an average yield of 30 boxes per tree.

In treatments involving the use of Carbowax (a polyethylene glycol) the chemicals were dissolved in the Carbowax and added directly to the spray tank. In all other treatments 1 pint per 100 gallons of a light emulsified oil was used.

Fruit drop records were made at frequent intervals following application of experimental treatments. Harvest dates were in accordance with commercial maturity standards for the particular variety.

Experimental Results

Accumulated percentages of fruit drop at harvest for Oldenburg, McIntosh, and Delicious are shown in Table I. The data clearly show that for these three varieties 2,4–dichlorophenoxyacetic acid was almost completely ineffective in controlling fruit drop. With McIntosh and Delicious the dates of application of this material (within the limits tested) showed no essential differences in effect on the resulting fruit drop. The addition of Carbowax to napthaleneacetic acid sprays on both Oldenburg and Delicious seemed to significantly increase effectiveness.

Results with the Winesap variety are shown in Fig. 1. In decided contrast to the results with other varieties tested the 2,4–dichlorophenoxyacetic acid treatments on this variety were greatly superior to naphaleneacetic acid in both intensity and duration of effect. Of interest

TABLE I—Effect of 2,4–Dichlorophenoxyacetic Acid and of Napthaleneacetic Acid Sprays on the Harvest Drop of Three Varieties of Apples

Treatment	Concentration (PPM)	Date Applied	Number days Following Spray Application	Fruit Drop Per cent (SEm)
Oldenburg				
Napthaleneacetic acid	10	Jul 20	19	7.3± 2.7
Napthaleneacetic acid +5 per cent Carbowax	10	Jul 20	19	4.4± 1.9
2, 4–Dichlorophenoxyacetic acid	10	Jul 20	19	81.3± 4.9
2, 4–Dichlorophenoxyacetic acid + 5 per cent Carbowax	10	Jul 20	19	72.5±11.4
Unsprayed	0	–	19	90.5± 2.7
McIntosh				
Napthaleneacetic acid	20	Aug 4	34	10.6± 5.6
Napthaleneacetic acid	20	Aug 21	17	9.4± 2.1
2, 4–Dichlorophenoxyacetic acid	20	Aug 4	34	27.3± 2.0
2, 4–Dichlorophenoxyacetic acid	20	Aug 21	17	30.2± 6.2
Unsprayed	0	–	–	36.8± 9.6
Delicious				
Napthaleneacetic acid	10	Aug 20	43	1.6± 0.2
Napthaleneacetic acid +5 per cent Carbowax	10	Aug 20	43	0.9± 0.1
Napthaleneacetic acid	10	Sept 10	22	2.0± 0.4
2, 4–Dichlorophenoxyacetic acid	10	Aug 20	43	11.5± 0.8
2, 4–Dichlorophenoxyacetic acid + 5 per cent Carbowax	10	Aug 20	43	12.5± 1.2
2, 4–Dichlorophenoxyacetic acid	10	Sept 10	22	12.9± 2.3
Unsprayed	0	–	–	15.3± 1.9

is the fact that the earlier spray of 2,4–dichlorophenoxyacetic acid (September 10) was significantly more effective than the September 24 treatment. A number of the trees that received the September 10 treatment failed to drop more than one or two sound fruit although they had a crop of 35 to 40 boxes. The relatively small standard errors (Fig. 1) are indicative of the uniformity of results of all 2,4–dichlorophenoxyacetic acid treatments. A combination spray including both chemicals was highly effective, but no more so than when 2,4–dichlorophenoxyacetic acid was applied singly on the same date.

The addition of Carbowax (not shown in Fig. 1) resulted in a significant increase in effectiveness of both napthaleneacetic acid (3.8 per cent drop) and 2,4–dichlorophenoxyacetic acid (0.8 per cent drop when applied on September 24).

Discussion

The high degree of variety selectivity of 2,4–dichlorophenoxyacetic acid in controlling the harvest drop of apples is an interesting feature of this chemical. No explanation can be offered for its effectiveness on Winesap and its complete failure to control drop on other varieties tested. It should be pointed out that the original test with this compound for control of fruit drop was made on this variety (1). It will be noted from the slope of the curves in Fig. 1 that in all 2,4–dichlorophenoxyacetic acid treatments fruit drop was at a fairly uniform rate throughout the duration of the experiment. Indeed, the lines are almost

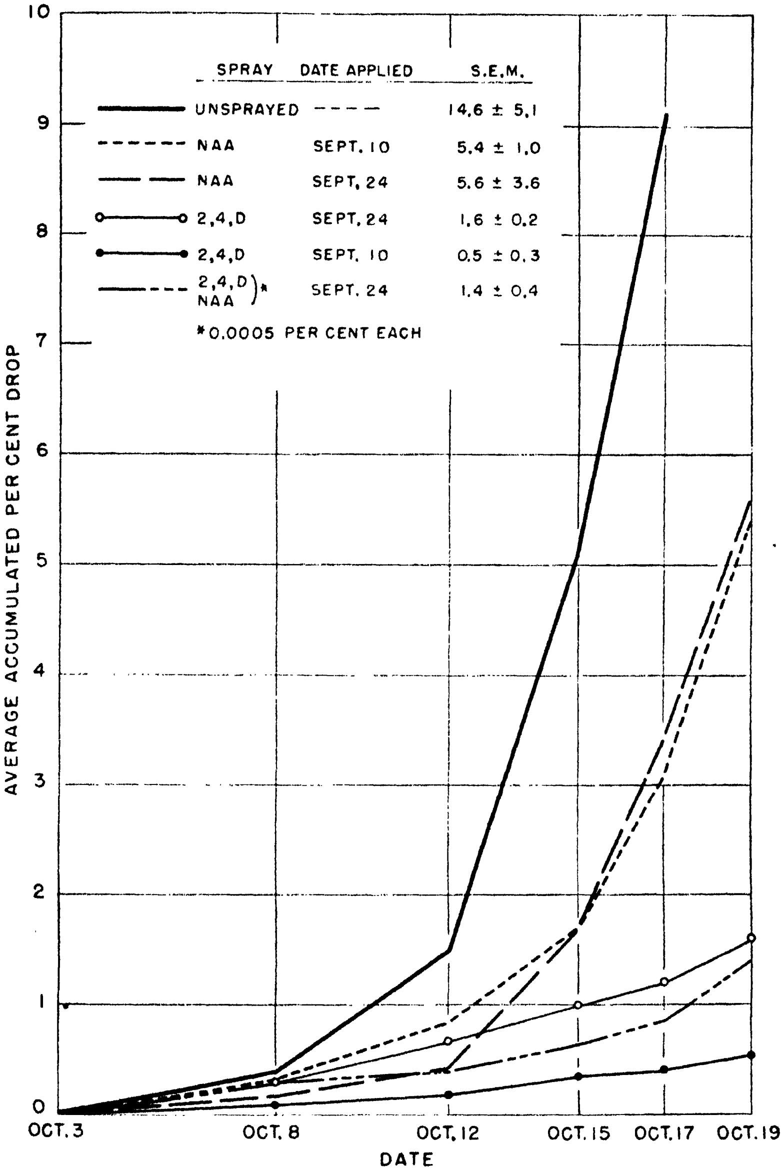

FIG. 1. Effect of 2,4–dichlorophenoxyacetic acid and of naphthaleneacetic acid sprays on the harvest drop of Winesap apples. Chemicals were applied at the rate of 10 ppm.

straight. This behavior is in decided contrast to the napthaleneacetic acid treatments which show an increase in rate of drop at each successive date with a very marked increase occurring from October 15 to October 19.

The fact that the early application of 2,4–dichlorophenoxyacetic acid was even more effective than one applied later (Fig. 1) is of considerable possible importance. This relatively long duration coupled with high intensity of effect suggests the possibility of combining this chemical with a late cover spray on Winesap thus eliminating the necessity of an extra spray during the busy harvest season. This possibility and the much lower cost as compared with napthaleneacetic acid are certainly advantages of considerable consequence.

While these results with 2,4–dichlorophenoxyacetic acid on Winesap are very promising, further experiments are needed to determine the effect on the physiology of the fruit and foliage before it can be recommended for extensive commercial use. Limited storage tests showed no detrimental effects of 2,4–dichlorophenoxyacetic acid on keeping quality of the fruit.

More extensive testing may possibly reveal other varieties on which 2,4–dichlorophenoxyacetic acid will be effective. It is not likely that concentrations much greater than 10 p.p.m. can be used without the possibility of injury, though this point was not thoroughly explored in the case of apples. There would seem to be no necessity of using a spray stronger than 10 p.p.m. on Winesap. With McIntosh 20 p.p.m. showed no visible injury. When sprayed on Bartlett pears, however, 2,4–dichlorophenoxyacetic acid in concentrations greater than 5 p.p.m. resulted in noticeable injury to leaves and buds.

In previous work (1) the addition of Carbowax significantly increased the effectiveness of napthaleneacetic acid sprays. In the present experiments the inclusion of this material significantly increased the intensity of effect in all cases. The fruit was harvested, however, before it could be determined whether the duration of effect was prolonged by the addition of Carbowax. Whether the benefit from adding Carbowax to the spray under western conditions is sufficient to justify the expense is problematical.

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2, 4–Dichlorophenoxyacetic Acid as a Spray to Reduce Harvest Fruit Drop of Apples

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Certain definite limitations attend the use of naphthaleneacetic acid as a preharvest spray to reduce fruit drop. The period of effectiveness of the spray is relatively short, and in order to obtain best results rather exact timing of application is essential. The correct time of spray application, in many instances, conflicts seriously with other important harvesting operations. A spray, therefore, with an intensity equal to that of naphthaleneacetic acid, but with longer duration, would be highly desirable.

In testing some new materials for delaying fruit abscission of apples, Batjer and Marth (1) found that the addition of Carbowax increased the effectiveness of naphthaleneacetic acid. They also reported that sprays containing .001 per cent of 2,4–dichlorophenoxyacetic acid were effective in reducing fruit drop for a period of 28 days, which was about double the period of effectiveness of naphthaleneacetic acid alone. The variety used in their experiment was Winesap.

During the late summer and fall of 1945, experiments were conducted by the present writers, wherein the possibilities of 2,4–dichlorophenoxyacetic acid (hereafter written 2,4–D) as a preharvest spray were further explored. The varieties tested were Delicious, York Imperial, Golden Delicious, and Stayman Winesap.

In preparing the sprays Carbowax 1500 was liquefied by heat and dissolved in water. The growth-regulating substances were dissolved in small amounts of alcohol and added slowly to water in the spray tank, with agitation.

Experimental Results

With the exception of the Delicious variety all data are included in Table I. Results on Stayman Winesap, for four plots receiving single applications on different dates, are also shown in Fig. 1, as accumulated per cent drop obtained at frequent intervals.

Delicious:—Experiments conducted on this variety at Beltsville, Md., were preliminary in character and the data are not presented because of the small number of replicates. The trials consisted of two-tree plots receiving 7 different treatments and five unsprayed trees. Of the 14 sprayed trees, eight received .001 per cent of 2,4–D alone, or in combination with .5 per cent of Carbowax 1500. Dates of application were August 6 and 13, and September 7; representing 38, 31, and 6 days, respectively, before the approximate commercial harvest date.

For the Delicious variety there was no significant difference between trees sprayed with 2,4–D and those unsprayed, in the number of dropped fruits throughout the course of the experiment, which was continued until October 25. Naphthaleneacetic acid showed charac-

TABLE I—EFFECTS OF 2,4-DICHLOROPHENOXYACETIC ACID (2,4-D), NAPHTHALENEACETIC ACID (NAA), AND CARBOWAX 1500 SPRAYS ON THE REDUCTION OF HARVEST FRUIT DROP OF YORK IMPERIAL, GOLDEN DELICIOUS, AND STAYMAN WINESAP APPLES

Treatment	Date of Spray Application	Approximate Number of Days Between Application and Commercial Harvest	Accumulated Per Cent Drop at Commercial Harvest	Accumulated Per Cent Drop at End of Experiment	Number of Days From Time of Application to End of Experiment
York Imperial (Beltsville, Md.)					
Unsprayed	——	4	13.8	67.1	29
0.001 per cent 2,4-D +0.25 per cent Carbowax	Sep 25	4	12.8	67.4	29
0.002 per cent 2,4-D +0.25 per cent Carbowax	25	4	12.6	69.7	29
York Imperial (Orrtanna, Pa.)					
Unsprayed	——	16	10.3	16.4	24
0.001 per cent NAA	Sep 26	16	5.3	9.4	24
0.001 per cent NAA +0.5 per cent Carbowax	26	16	3.4	7.5	24
0.001 per cent 2,4-D	26	16	6.8	14.3	24
0.002 per cent 2,4-D	26	16	6.8	11.1	24
0.002 per cent 2,4-D +0.5 per cent Carbowax	26	16	7.8	16.2	24
Differences necessary for significance at 5 per cent point	——	—	4.5	7.2	—
Golden Delicious (North Mountain, W. Va.)					
Unsprayed	——	15	8.5	—	—
0.001 per cent NAA	Sep 12	15	6.8	—	—
0.001 per cent 2,4-D	12	15	8.6	—	—
0.001 per cent NAA +2,4-D	12	15	6.1	—	—
0.001 per cent NAA +0.5 per cent Carbowax	12	15	5.4	—	—
0.001 per cent 2,4-D +0.5 per cent Carbowax	12	15	6.7	—	—
0.001 per cent NAA +0.001 per cent 2,4-D + 0.5 per cent Carbowax	12	15	5.2	—	—
0.001 per cent NAA +0.001 per cent 2,4-D +0.25 per cent Carbowax	12	15	5.2	—	—
Differences necessary for significance at 5 per cent point	——	—	2.8	—	—
Stayman Winesap (Orrtanna, Pa.)					
Unsprayed	——	36	17.8	54.4	55
0.001 per cent 2,4-D +0.5 per cent Carbowax	Aug 28	36	2.8	7.7	55
0.001 per cent 2,4-D +0.001 per cent NAA +0.5 per cent Carbowax	28	36	2.7	5.4	55
Unsprayed	——	28	15.3	53.1	47
0.001 per cent 2,4-D +0.5 per cent Carbowax	Sep 5	28	3.2	7.6	47
0.001 per cent 2,4-D +0.001 per cent NAA +0.5 per cent Carbowax	5	28	3.3	6.2	47
Unsprayed	——	23	14.1	52.5	42
0.001 per cent 2,4-D +0.5 per cent Carbowax	Sep 10	23	2.0	5.8	42
0.001 per cent 2,4-D +0.001 per cent NAA +0.5 per cent Carbowax	10	23	1.5	3.8	42
Unsprayed	——	12	11.9	51.6	31
0.001 per cent 2,4-D +0.5 per cent Carbowax	Sep 21	12	3.7	8.1	31
0.001 per cent 2,4-D +0.001 per cent NAA +0.5 per cent Carbowax	21	12	1.4	5.0	31

teristic effectiveness which was greatly increased by the addition of Carbowax.

York Imperial:—Spray plots were established at Beltsville, Md., and Orrtanna, Pa. The plots at Beltsville contained six randomized trees each and treatments consisted of .001 per cent and .002 per cent

of 2,4–D plus .25 per cent of Carbowax. The data in Table I show no significant difference in fruit drop of sprayed and unsprayed trees.

Thirty-eight trees were selected at Orrtanna to receive five different spray treatments on six trees each, leaving eight unsprayed as controls. Instead of single-tree randomization, groups of three trees at different points in the orchard constituted the experimental plan. This design was adopted for best utilization of uniform trees and crop, and to minimize the possibility of spray drift to nearby trees. Wherever possible a buffer tree separated the plots receiving the different spray applications. The average orchard air temperature at the time of application was 76 degrees F.

The average crop per tree was 16.7 bushels, and at harvest there was no difference in size of apples in the various treatments.

The only sprays showing effectiveness were those containing naphthaleneacetic acid, and the highest intensity was obtained when Carbowax was added. As in the previously described test on York Imperial at Beltsville, 2,4-D did not significantly reduce fruit drop.

Golden Delicious:—This experiment was conducted at North Mountain, West Virginia, and was designed to study the effects of naphthaleneacetic acid and 2,4–D, separately and in combination, with and without Carbowax. A total of 135 carefully selected trees were divided for seven spray treatments, each of which was applied to 15

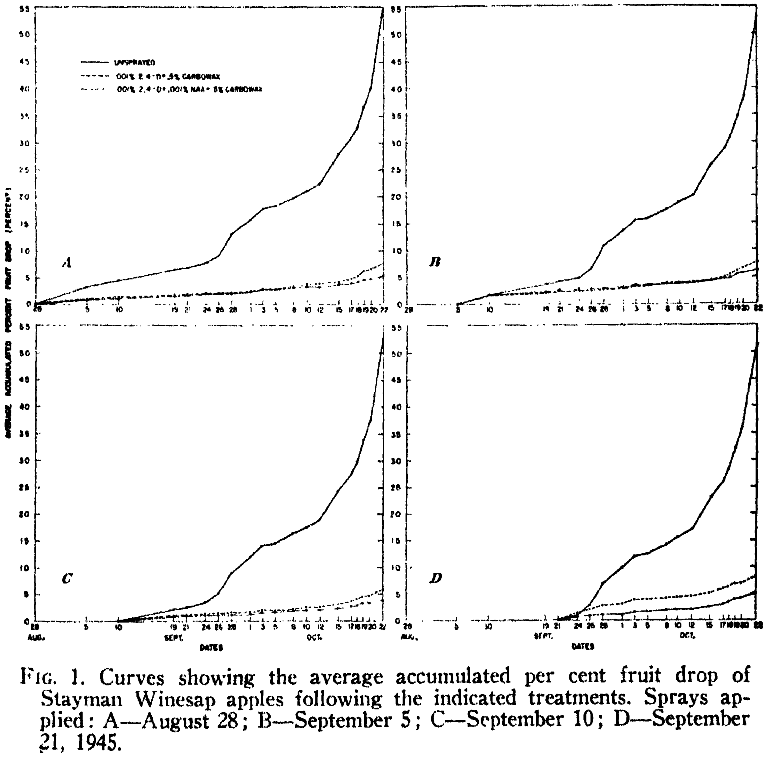

FIG. 1. Curves showing the average accumulated per cent fruit drop of Stayman Winesap apples following the indicated treatments. Sprays applied: A—August 28; B—September 5; C—September 10; D—September 21, 1945.

trees randomized in groups of five. Thirty trees similarly randomized remained unsprayed. Temperatures well above 70 degrees F prevailed in the orchard at the time of spraying.

Yield was remarkably uniform and the average of the plots was 10.3 bushels per tree. Size of fruit was not reduced by any treatment.

The accumulated per cent drop data, secured at frequent intervals and at harvest, indicate that none of the treatments employed in this orchard were materially effective. Sprays containing naphthaleneacetic acid plus Carbowax show a statistically significant reduction in drop in comparison with the unsprayed trees; however, the economic importance of this reduction is doubtful.

No factor or group of factors associated with this experiment can adequately explain the apparent lack of response of these Golden Delicious to spray applications of naphthaleneacetic acid, which normally reduce drop in most varieties to a considerable degree.

Stayman Winesap:—Sprays containing 2,4–D were applied at different intervals to Stayman Winesap trees at Orrtanna, Pa. Each treatment consisted of 10 trees randomized in groups of five. The trees were quite uniform in size and in the number of fruits borne. All sprays were applied on calm days. The temperature on August 28 was 72 to 74 degrees F; September 5, 72 to 76 degrees F; September 10, 71 degrees; and September 20, 72 degrees. Rather severe wind and rain storms occurred on August 30 and September 6. The data as shown in Table I and Fig. 1 indicate that sprays containing .001 per cent of 2,4–D had a pronounced effect on this variety in reducing fruit drop. The most important consideration is the fact that 2,4–D had an exceptionally long period of effectiveness.

Many fruits on all trees were cracked and a high percentage of the early dropped apples of the unsprayed trees were of this type. On the other hand, cracked apples remained on the 2,4–D-sprayed trees until harvest. Some, however, rotted on the tree and in many instances the rotted fruits separated from the stems and fell to the ground, leaving the stems firmly attached to the tree. The experiment was terminated about 19 days after the commercial harvest date, and at this time stems of apples on all trees sprayed with 2,4–D resisted separation from the spurs, although not to the extent of making picking difficult. Fruits from unsprayed trees fell at the slightest touch.

Average yield per tree in bushels was 10.2, and the average size of fruits was not significantly different in any of the plots.

From the curves for accumulated per cent drop in Fig. 1–D it can be deduced that the addition of naphthaleneacetic acid to 2,4–D in the latest application (12 days before harvest) slightly increased the efficiency of the spray. The difference is probably of little significance, although there is an indication that 12 days before commercial harvest either 2,4–D was beginning to lose efficiency or the effective range for naphthaleneacetic acid was being approached.

Discussion and Conclusions

Under the conditions of these experiments preharvest sprays containing .001 per cent and .002 per cent of 2,4–dichlorophenoxyacetic

acid, alone and in combination with .5 per cent Carbowax, were ineffective in materially reducing fruit drop of Delicious, York Imperial, and Golden Delicious. On the other hand, single applications of 2,4–D in a concentration of .001 per cent, made 36, 28, 23, or 12 days before commercial harvest, were all highly effective in preventing fruit drop of Stayman Winesap. On the basis of our experiments, the value of Carbowax 1500 with 2,4–D sprays is questionable, although this cannot be assumed with Stayman Winesap, as no trees were sprayed with 2,4–D alone in this orchard. Combining naphthaleneacetic acid with 2,4–D did not significantly increase the intensity of effect, except possibly when the application was made 12 days before normal harvest. Thus it appears that 2,4–D shows outstanding promise as a preharvest spray for the Stayman Winesap variety because of the long duration of its effectiveness. It also offers flexibility in timing of applications, lack of which heretofore has caused some interference with other harvest operations and labor management. It may also be possible to combine the harvest-drop spray with the late codling-moth spray. This appears quite feasible unless certain spray mixtures are employed that may reduce the effectiveness of the 2,4–D.

Just why 2,4–D shows such specificity for Winesap (1) and Stayman Winesap varieties remains to be determined. Probably other sorts not yet tested will be found to be responsive. Tukey and Hamner (2) have recently reported that fruit adhered well on one tree of Kendall following a single aerosol treatment with 2,4–D. Although the number of varieties influenced may be limited, the low cost of 2,4–D and the long period of highly intensive effect may be sufficient to justify the adoption of this material for responsive varieties.

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The Use of the Airplane in Applying Hormone Sprays for the Control of Pre-Harvest Drop of Apples

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AIRPLANE application of hormone chemicals to fruits was first tried in the Pacific Northwest during the season of 1944. In this area in 1945 it is estimated that 15,000 to 20,000 acres of apples and pears were treated with hormones by this method. The writers made studies during the 1945 season: (a) to compare the efficiency of the airplane application with that of the conventional application of naphthaleneacetic acid, (b) to study time of application as a possible factor in the success of the airplane method, and (c) to determine the relationship of concentration to effectiveness of hormone sprays when applied by airplane.

MATERIALS AND METHODS

All conventional sprays were applied using a standard portable power sprayer with approximately 500 pounds pressure at the nozzle. The airplane treatments were applied from airplanes equipped with two rotary wire brushes which revolved at approximately 2500 rpm at an air speed of 90 miles per hour. The spray material was dispersed from these revolving brushes in the form of minute droplets which were forced down through the trees by air turbulance created by the plane. Applications were made from 6 to 10 feet above the tops of the trees in each row. The airplane treatments were applied only during calm periods when air movement was at a minimum so that a relatively thorough dispersion of the spray through the trees was attained with a minimum of drift. From one to two buffer rows were left between treated rows, depending upon the planting distance and the drift obtained on a particular day.

The conventional sprays all consisted of naphthaleneacetic acid at 10 ppm in ⅛ per cent of "summer oil." With the airplane the standard commercial procedure is to apply approximately 48 grams of naphthaleneacetic acid dissolved in 5 gallons of solution (containing 40 per cent of summer oil) to one acre of fruit trees. In the conventional method of application, usually about the same amount of naphthaleneacetic acid (48 grams) is used per acre of mature trees; however, this amount of hormone is contained in 1200 gallons of solution rather than 5 gallons — as is the case in the airplane method. Therefore, in the airplane method the hormone is applied in a greatly concentrated form (2400 ppm) which is approximately 240 times more concentrated than the conventional spray. In these experiments involving the airplane the concentration of naphthaleneacetic acid was varied from 300 to 2400 ppm and the volume of material used was in all cases at the approximate rate of 5 gallons per acre. The amount of summer oil (2 gallons or 40 per cent) used in these various airplane sprays was held constant.

The trees used in the different experiments varied in age from 20 to 40 years. All trees were in moderately good vigor and were carrying a full crop of fruit. Fruit drop records were made at frequent intervals

following the application of experimental treatments, and harvest dates were in accord with accepted standards for optimum fruit maturity.

RESULTS

A simple comparison of the airplane method and the conventional method is shown in Table I. In this block of 35-year-old Winesap

TABLE I—THE EFFECT OF AIRPLANE VS. CONVENTIONAL APPLICATION OF NAPHTHALENEACETIC ACID ON THE PRE-HARVEST DROP OF WINESAP APPLES*

Method of Application	Spray Concentration (Ppm)	Trees Per Treatment	Average Cumulative Per Cent Drop (Days After Spray Application) 11	14	18	20
Airplane	2400	6	0.7	1.2	3.1	5.7 ± 1.3
Conventional	10	8	0.4	0.5	1.1	1.6 ± 0.7
Unsprayed	0	9	1.4	2.5	6.5	12.0 ± 2.6

*Sprays were applied on September 9, 1945.

trees a severe infestation of codling moth was reflected in a large number of wormy fruits in the drops recorded. Nevertheless, the data indicate that the airplane method was effective in reducing the drop of fruit, but the conventional spray was considerably more effective. Both the airplane and the conventional sprays were applied at standard strength, 2400 and 10 ppm, respectively.

Considerable interest has developed in the possibility of spraying Winesap and Delicious apples at the same time with the airplane. This would obviate the necessity of skipping rows or blocks where these two varieties are interplanted, and would make possible in many instances the complete spraying of an entire orchard at one time. To study this possibility, treatments were applied in a block of large, 40-year-old Winesap trees which were in good vigor, and were reported by the operator to be characteristically "heavy droppers." The results of this experiment are shown in Table II. The earliest application was made on September 6, the day on which all the Delicious trees in this orchard were sprayed by airplane. From the data in Table II it can be seen that the airplane spray, applied to Winesap trees on that day, "ran out" before harvest on October 18 — indicating clearly that this spray was applied too early for greatest effectiveness. While subsequent airplane applications on September 13 and September 27 were considerably more effective, yet the data show that the conventional sprays applied on the same dates were somewhat superior.

TABLE II—EFFECT OF TIME OF APPLICATION OF AIRPLANE AND CONVENTIONAL HORMONE SPRAYS ON THE PRE-HARVEST DROP OF WINESAP APPLES

Method of Application	Spray Concentration (Ppm)	Date Applied	Trees Per Treatment	Average Cumulative Per Cent Drop (Date Recorded) Oct 6	Oct 13	Oct 16	Oct 18
Airplane	2400	Sep 6	6	0.7	7.7	16.5 ± 3.3	23.1
Airplane	2400	Sep 13	9	0.6	—	9.2 ± 1.6	—
Airplane	2400	Sep 27	11	0.4	2.2	6.8 ± 0.9	10.9
Conventional	10	Sep 13	9	0.4	2.6	7.2 ± 0.7	10.2
Conventional	10	Sep 27	10	0.4	1.3	3.7 ± 0.8	6.0
Unsprayed	0	——	11	2.8	15.1	27.0 ± 2.3	34.0

In order to determine whether or not the concentration of airplane sprays could be reduced without limiting the effectiveness of the spray, a one-half strength (1200 ppm) airplane spray was compared with full strength airplane (2400 ppm) and conventional (10 ppm) sprays in a block of 20-year-old Delicious apple trees. After 21 days (Table III), the drop on all treated trees was significantly lower than that

TABLE III—EFFECT ON THE PRE-HARVEST DROP OF DELICIOUS APPLES OF STANDARD AND REDUCED AIRPLANE APPLICATIONS OF NAPHTHALENEACETIC ACID IN COMPARISON WITH STANDARD CONVENTIONAL APPLICATION

Method of Application	Spray Concentration (Ppm)	Trees Per Treatment	Average Cumulative Per Cent Drop (Days After Spray Application*)			
			5	11	17	21**
Airplane	2400	13	0.2	0.6	1.0	1.5
Airplane	1200	13	0.2	0.8	1.7	2.2
Airplane, repeat	1200	10	0.2	0.6	1.1	1.5
Conventional	10	15	0.1	0.4	0.7	1.4
Unsprayed	0	14	0.2	1.8	5.1	8.8

*Sprays were applied Sep 17, 1945; repeat spray was applied Sep 18, 1945.
**Difference ne essary for significance at 5 per cent point: 1.5.

of the check trees, but no one treatment was clearly better than any of the other treatments. The one-half strength airplane spray seems to have given essentially the same control of fruit drop as the other airplane treatments.

Of interest is the fact that when harvest was delayed until 23 days after treatment on several trees in both the airplane (2400 ppm) and conventional spray treatments, the rate of fruit drop increased markedly. Apparently, therefore, with both methods of application the effect of the hormone had been largely dissipated. This evidence, together with the data shown in Table II (September 6 application), would seem to indicate that the effective period of naphthaleneacetic acid when applied by airplane is no longer than when applied by the conventional method.

Results of further reductions in the concentration of the airplane spray applied to Winesap apples are shown in Table IV. It may be seen from these data that all three concentrations of naphthaleneacetic acid applied by airplane significantly reduced fruit drop. Results with one-third (800 ppm) and standard strength (2400 ppm) sprays were

TABLE IV—EFFECT ON THE PRE-HARVEST DROP OF WINESAP APPLES OF STANDARD AND REDUCED AIRPLANE APPLICATIONS OF NAPHTHALENEACETIC ACID IN COMPARISON WITH STANDARD CONVENTIONAL APPLICATION

Method of Application	Spray Concentration (Ppm)	Trees Per Treatment	Average Cumulative Per Cent Drop (Days After Spray Application*)			
			12	22	24	26**
Airplane	2400	11	0.4	1.2	1.7	2.3
Airplane	800	8	0.2	1.4	1.9	2.4
Airplane	300	5	0.3	2.2	2.7	3.3
Conventional	10	9	—	—	0.7	1.0
Unsprayed	0	8	0.6	3.8	5.0	6.8

*All sprays were applied on September 30, 1945.
**Difference necessary for significance at 5 per cent point: 1.6.

essentially the same while one-eighth strength (300 ppm) spray was only slightly less effective. The conventional spray, as was indicated in previous Winesap experiments, was somewhat superior to the airplane spray.

Airplane application of hormone sprays is clearly an advantageous method from the point of view of orchard management. The large acreage covered during the 1945 season is ample evidence of the interest in this method of applying hormones. Results of these studies show clearly that airplane sprays are effective in reducing fruit drop. In some of the experiments reported the conventional method seemed to give significantly greater intensity of effect while in others little or no difference was obtained. From these data it is apparent that the magnitude of the differences between the two methods is not large, but further testing is necessary in order to establish more definitely their comparative relationship.

Results with both Delicious and Winesap apples strongly indicate that the effective period of the naphthaleneacetic acid spray when applied with the airplane is of no longer duration than when applied by the conventional method. Because of this, it does not seem likely that varieties maturing as far apart as Delicious and Winesap can be sprayed at the same time for satisfactory control of fruit drop.

The mechanism of action of hormone sprays, particularly the airplane sprays where only 5 gallons of a highly concentrated solution are applied per acre, is of considerable interest. It has been suggested (1) that possibly hormone sprays have an effect on the physiological processes of the tree of a general systemic nature, other than the local response at the point of abscission of the fruit. Some work was carried out in 1945 to investigate this point in which 120 apples and their adjacent spur leaves on three trees were bagged before airplane application of hormones. Each bagged fruit was matched by a tagged fruit which was left exposed to the spray. Bags were removed from the covered apples as soon as the spray had been applied. Drop records taken on these trees revealed that considerably more "bagged fruits" dropped than sprayed fruits, indicating that the effect was not systemic in the sense of being transmitted from one fruiting spur to another in a localized area.

In order to determine if transmission of effect is obtained from leaves to fruit on the same spur, a vigorous Winesap tree carrying a full crop was selected for hand application of naphthaleneacetic acid to 100 apples per treatment as follows: (a) 10 ppm solution (in one-eighth per cent of oil) applied to spur leaves only with a brush, great care being exercised not to touch the fruit stems or the fruit, (b) 10 ppm in one-eighth per cent of oil sprayed on both spur leaves and fruit with a hand atomizer, (c) 2400 ppm in 40 per cent of oil applied to spur leaves only with a stirring rod to simulate airplane coverage of three to five droplets per leaf and (d) no treatment. Twenty-six days after application it was found that the three treatments significantly reduced fruit drop in comparison with the check, but there was no apparent difference between treatments in their respective effectiveness.

While these data are somewhat limited, they do suggest that the spraying of spur leaves alone on a fruiting spur is sufficient to delay fruit abscission. This is contrary to the popular conception in which it is deemed necessary to actually make contact with the stem in order to achieve control of fruit drop with hormone sprays. Thus with airplane spraying, while many fruits and stems are missed by the spray, it is rare that at least one of a group of spur leaves is not reached by several droplets of spray material.

In the test described above, a solution of only 10 ppm applied to leaves only on fruiting spurs was sufficient to control drop. This would seem to indicate the possibility of drastically reducing the concentration of airplane sprays without sacrificing effectiveness. It has been shown in these experiments that concentrations considerably lower than 2400 ppm (airplane method) were effective in delaying fruit drop. However, further work is necessary before the extent to which concentrations might be reduced can be definitely established.

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Inheritance of Fire Blight Resistance in Progenies of Crosses Between Several Apple Varieties

By R. C. Moore,[1] *Virginia Agricultural Experiment Station, Blacksburg, Va.*

Fire blight, a destructive disease of apples caused by *Erwinia amylovora* (Burr.) Wins., *et al*, occurs at irregular intervals in varying degrees of severity killing blossoms, branches, and fruits. Heald (1) summarizes the symptoms and history of the disease.

Varieties have been found to differ in the extent of injury by blight. Hildebrand and Heinicke (2), Nixon (3), Shaw (4), and Thomas and Parker (6) have noted varietal differences in severity of blight injury. However, little is known of the manner in which parent apple varieties transmit blight resistance or susceptibility to seedling progenies.

The data herein presented were obtained in 1940 at Blacksburg in connection with the apple breeding program of the Department of Horticulture of the Virginia Agricultural Experiment Station. The original purpose was to determine blight resistance of individual F_1 seedlings of controlled crosses. When there appeared to be marked differences in blight resistance between the various seedlings, and between seedling populations from different crosses, the data were analyzed further in an attempt to determine the manner of inheritance of the resistance.

At the time of inoculation, 1875 of these hybrid apple seedling trees were growing actively in fertile soil under intensive cultivation. They were spaced approximately 2 feet apart in rows 4 to 8 feet apart. Trees in Nursery A were 4 years of age and growing on level land except that the Winesap x Jonathan population and approximately one-half of the Jonathan x Rome population were located on slightly higher elevations than other trees of this nursery. All trees in Nursery B, which were 3 years old, were growing in level bottom land near a small stream.

Method of Inoculation

Inoculum for the initial treatment was obtained from freshly blighted shoots of the Mother apple variety. Approximately 20 partially wilted shoots were macerated in a pint of tap water to obtain a bacterial suspension, which was renewed each 3 hours during the periods when inoculations were being made.

Three actively growing terminal shoots on each tree were selected for inoculation with the blight suspension, each selected shoot being inoculated as near its tip as feasible. A drop of the suspension was placed upon the shoot tip, a five-pointed needle pressed through the drop into the apple tissue, and then another drop added to the punctured area.

Inoculations of trees in Nursery A were made from June 4 to 6; in Nursery B, on June 6 and 7. Wilting of some shoot tips and leaves

[1]The writer wishes to express his appreciation to Dr. Boyd Harshbarger for assistance with analyses.

was noticeable by June 10. By June 13 it was apparent that shoots of some trees had not become infected by blight. It was desired to determine whether the failure resulted from natural immunity or from faulty inoculation. The inoculation, then, was repeated from June 14 to 21, on three additional actively growing shoots of each uninfected tree. Showers were frequent during this period. On June 20 it was noted that active end growth of a few trees had almost ceased.

Trees that showed no effects from the first two inoculations were given a third inoculation on June 29. Only trees with actively growing terminal shoots were included. By June 29 shoot tissue of many trees had hardened somewhat and terminal buds were forming. Shaw (4) has mentioned morphological and physiological maturity of tissues as one of the major influences in susceptibility to fire blight.

Excellent growing conditions prevailed immediately preceding and during the greater part of the inoculating period. Days were warm and sultry and showers frequent, especially during the nights. No natural blight infection occurred on any of these trees in 1940.

On many resistant trees nearly every available terminal shoot received an inoculation by one of the three repeated treatments. Freshly blighted York Imperial shoots furnished the inoculum for the second and third treatments. The second inoculation infected only a few shoots and the third inoculation produced almost no infections.

Analysis of Data

The two measurements recorded for each terminal shoot of each tree were: (a) inches length of the current season growth at the time of inoculation; and (b) length of the blighted portion of the shoot 50 days after inoculation. The per cent of blight infection of the shoot was determined empirically by dividing (b) by (a). Thus, where blight injury extended beyond the annual ring into older apple tissue, the per cent (or ratio) was greater than 100. The per cent of blight injury of each tree was determined by an average of three inoculated shoots.

In Table I the population of each parental cross has been arrayed in classes according to amount of blight. The class intervals represent the extent to which shoots were blighted, based upon an average of three shoots of each tree. The numbers in the class interval columns indicate the number of trees blighted, to the extent indicated by the respective class intervals.

As shown in Table II, four criteria were tested as to their effectiveness in dividing populations into blight resistant and susceptible classes. The purpose was to determine whether or not there were significant segregations. Criterion 1, "Infection by blight versus no infection", was not considered a reliable criterion since it failed to take into account the resistance indicated by slight infection of the shoot tip. Eleven of the 14 populations segregated significantly at the 1 per cent level when measured by the second criterion, as shown in columns four and five of Table II. Here, the division point between the resistant and susceptible classes was 1 inch from the annual ring in the direction of the shoot tip; and two most severely blighted of the

TABLE I—DISTRIBUTION BY CLASS INTERVALS, WITH RESPECT TO BLIGHT INFECTION OF SEVERAL F_1 APPLE PROGENIES

Class Intervals*	Nursery A Number of Seedlings								
	Mel × Jon	Mel × Low	Jon × Rom	Mel × Rall	Win × Opal	Win × Rom	Sch × Low	Win × Jon	Win × Del
0–10	—	10	3	5	17	205	28	15	93
11–20	—	3	—	2	1	18	2	1	16
21–30	—	2	—	1	5	23	1	4	4
31–40	—	1	3	3	4	44	5	5	21
41–50	—	2	2	2	3	43	2	6	19
51–60	2	3	1	2	4	38	4	2	14
61–70	—	4	2	2	3	19	3	3	6
71–80	—	4	1	5	4	36	1	—	13
81–90	1	2	1	2	4	20	2	3	11
91–100	—	4	2	4	2	20	3	1	12
101–110	—	3	6	—	3	10	—	—	6
111–120	1	3	5	2	2	25	2	—	7
121–130	1	7	4	4	7	20	2	1	5
131–140	1	7	3	6	3	18	3	—	6
141–150	—	1	3	2	4	8	1	—	1
151–160	2	6	1	2	2	9	2	—	—
161–170	—	3	8	—	1	7	—	—	2
171–180	—	3	3	—	2	6	—	—	1
181–190	1	4	3	1	3	3	—	—	2
191–200	1	3	2	—	—	3	—	—	1
201–210	—	5	1	2	1	1	—	—	—
211–220	—	1	—	—	—	5	—	—	—
221–230	—	1	3	—	—	1	—	—	—
231–240	1	1	—	2	—	—	—	—	1
241–250	—	1	—	—	—	—	2	—	—
251–260	—	2	1	—	—	1	—	—	—
261–270	—	2	1	2	—	2	—	—	—
271–280	—	—	1	2	—	—	—	—	—
281–290	—	—	2	—	—	2	—	—	—
291–300	—	—	—	—	—	—	—	—	—
301–310	—	—	—	1	—	—	—	—	—
311–320	—	—	—	—	—	—	—	—	—
321–330	—	3	1	—	—	—	—	—	—
331–340	—	—	—	—	—	1	—	—	—
341–350	—	—	—	—	—	—	—	—	—
351–360	—	—	—	—	—	—	—	—	—
361–370	—	—	2	—	—	—	—	—	
371–380	—	—	—	—	—	—	—	—	
381–390	—	—	—	—	—	—	—	—	
391–400	—	1	1	1	—	—	—	—	
Totals..	11	92	66	55	75	588	63	41	241

Class Intervals*	Nursery B—Number of Seedlings								
	Win × Yor	Ark × Del	Win × Rom	Win × Del	Win × Rall				
0–10	2	25	45	46	35	—	—	—	—
11–20	—	1	6	2	4	—	—	—	—
21–30	—	2	6	—	5	—	—	—	—
31–40	3	7	16	12	5	—	—	—	—
41–50	2	3	14	8	8	—	—	—	—
51–60	1	1	7	1	5	—	—	—	—
61–70	2	3	12	6	5	—	—	—	—
71–80	5	2	15	7	2	—	—	—	—
81–90	—	1	6	2	2	—	—	—	—
91–100	12	4	65	9	8	—	—	—	—
101–110	8	3	28	8	8	—	—	—	—
111–120	8	11	32	2	6	—	—	—	—
121–130	8	3	19	2	5	—	—	—	—
131–140	4	1	4	3	8	—	—	—	—
141–150	2	1	6	—	2	—	—	—	—
151–160	3	—	1	1	1	—	—	—	—
161–170	—	2	5	—	1	—	—	—	—
171–180	1	1	—	—	1	—	—	—	—
181–190	—	—	1	—	—	—	—	—	—
191–200	—	—	1	—	2	—	—	—	—
Totals...	61	71	289	109	113				

*Length of blighted portion of shoot divided by length of current season growth at the time of inoculation. Class intervals with values above 100 indicate that blight invaded beyond the annual ring, into older apple tissue.

TABLE II—CALCULATED CHI-SQUARE VALUES FOR F_1 POPULATIONS OF CROSSES BETWEEN APPLE VARIETIES AND PER CENT OF THE POPULATIONS OCCURRING IN THE MOST HEAVILY INFECTED OF THE TWO CLASSES, WHEN MEASURED BY FOUR DIFFERENT CRITERIA

Parent Varieties	Number of Seedlings	Infection by Blight Versus No Infection		Blight Invasion Extended to Within 1 Inch of Annual Ring or Further, Versus Extended No Nearer Than 1 Inch of the Annual Ring				Blight Extension Beyond Annual Ring Versus Extension No Further Than Annual Ring	
				Two Out of Three Shoots Used		All Three Used			
		X^2	Per Cent of Population	X^2	Per Cent of Population	X^2	Per Cent of Population	X^2	Per Cent of Population
		Criterion 1		Criterion 2		Criterion 3		Criterion 4	
Nursery A									
Melon ×Jonathan	11	0.78	100.00	9.25	81.82	6.84	100.00	9.10	100.00
Melon ×Lowry	92	4.59	98.91	43.32	70.65	18.92	83.70	28.86	82.61
Jonathan ×Rome	66	4.70	100.00	59.34	83.33	23.91	90.91	26.66	86.36
Melon ×Ralls Seedling	55	0.81	96.36	13.95	61.82	9.47	81.82	16.29	81.32
Winesap ×Opalescent	75	0.85	96.00	4.53	49.33	0.003	61.33	0.47	58.67
Winesap ×Rome	588	2.81	95.07	12.91	30.27	3.01	58.16	6.10	49.66
Schoharie ×Lowry	63	5.91	85.72	2.12	28.57	4.12	49.21	3.58	42.86
Winesap ×Jonathan	41	15.45	78.05	21.45	2.44	4.06	46.34	7.01	34.15
Winesap ×Delicious	241	0.59	92.12	15.14	25.31	8.93	52.28	19.24	40.66
Average			93.35		37.44		61.44		54.73
Nursery B									
Winesap ×York	61	0.61	98.00	19.21	22.00	14.02	12.00	11.96	53.00
Winesap ×Rome	289	6.53	93.08	13.01	33.22	11.16	20.07	0.01	36.70
Winesap ×Ralls Seedling	113	0.20	97.35	6.62	55.75	5.44	38.94	0.64	32.74
Arkansas Black ×Delicious	71	18.37	87.32	8.16	60.56	4.85	40.84	0.09	38.00
Winesap ×Delicious	109	5.05	92.64	16.95	63.30	18.56	47.71	18.56	16.51
Average			93.68		46.47		31.91		35.39

Minimum X^2 for significance: 6.635.

three inoculated shoots were used in classifying each seedling. This was considered an advantageous division point since it eliminated the effect of the annual ring in checking the progress of the blight organism through the shoot tissue. Only the two most severely blighted shoots were used in Criterion 2, which was considered a more critical test of segregation than Criterion 3, in which all 3 shoots were used.

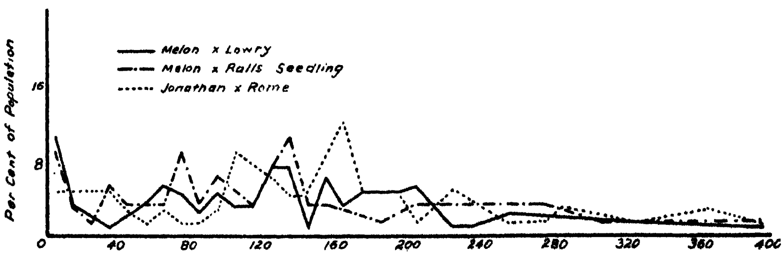

FIG. 1. Segregations for resistance to fire blight in 4-year-old hybrid apple populations showing least resistance.

In Criterion 4 it seemed likely that the annual ring tissue might impose a mechanical obstruction to further invasion by the blight organism. For this reason the annual ring did not appear to be a satisfactory division point for determining resistance and susceptibility.

Populations of Winesap x Opalescent and Schoharie x Lowry in Nursery A and of Winesap x Ralls Seedling in Nursery B failed to show significant segregation when tested by any of the four criteria.

The data from Table I are shown graphically in Figs. 1 to 5. Figs. 1, 2 and 3 include the trees of Nursery A; Figures 4 and 5, those of Nursery B. Populations with similar graph lines have been grouped in the various figures.

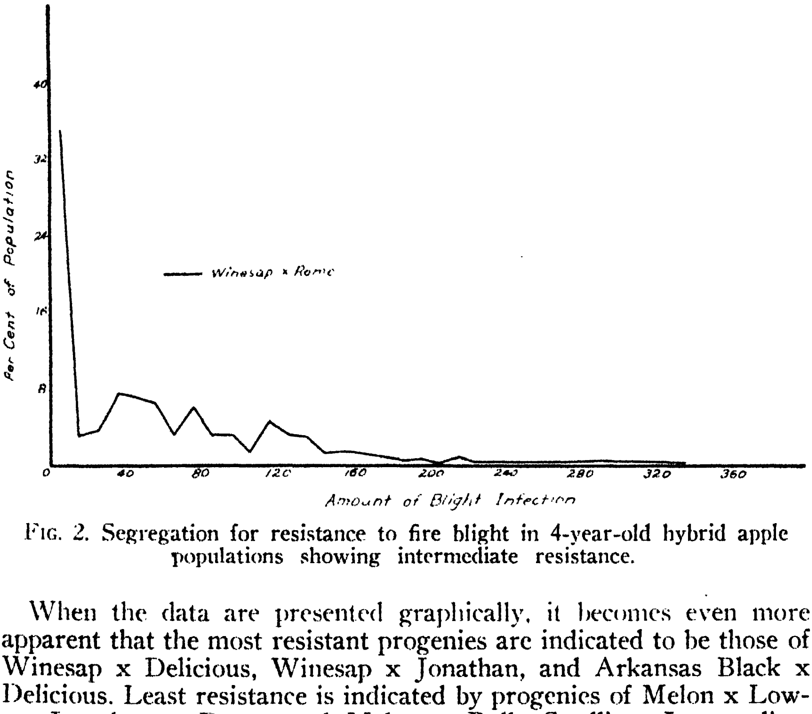

FIG. 2. Segregation for resistance to fire blight in 4-year-old hybrid apple populations showing intermediate resistance.

When the data are presented graphically, it becomes even more apparent that the most resistant progenies are indicated to be those of Winesap x Delicious, Winesap x Jonathan, and Arkansas Black x Delicious. Least resistance is indicated by progenies of Melon x Lowry, Jonathan x Rome, and Melon x Ralls Seedling. Intermediate amount of resistance is indicated in the populations of Winesap x Rome and Winesap x York.

An unaccountable inconsistency occurred between the Winesap x Rome population of Nursery A and that of Nursery B, in that a large proportionate part of the Nursery A population occurred in the 0–10 blight class; while in Nursery B the 100 class contained a large part of the population.

No comparable data for degree of blight resistance of parent varieties were obtained. Observations over a period of years, of resistance to natural blight infection of mature parent trees, indicate varietal resistance to be about as follows:

Resistant: Delicious, Schoharie, Arkansas Black, and Winesap.

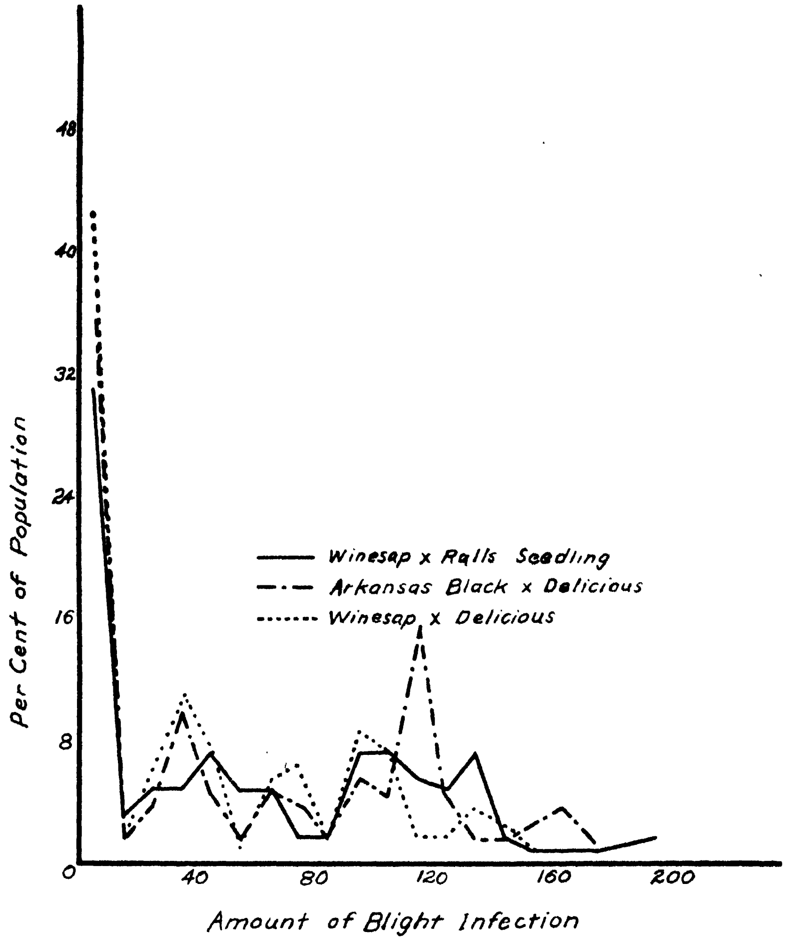

FIG. 3. Segregation for resistance to five blight in 4-year-old hybrid apple populations showing the greatest resistance.

Moderately Resistant: Lowry and Ralls Seedling.

Susceptible: Melon, Jonathan, York Imperial, and Rome Beauty. On the basis of these observations and the segregations appearing in the different populations under study, it appeared that crosses between the most resistant parents produced, as might be expected, the greatest proportion of resistant seedlings.

The general appearance of the F_1 distributions as a group bore considerable resemblance to an F_2 segregation derived from crossing fairly homozygous parents. In view of this resemblance, tests were made for goodness of fit to one of the Mendelian ratios. Two methods were tried for dividing the arrays into proportionate parts; the first an arbitrary division into fourths, sixteenths or sixty-fourths; the second a division based upon the occurrence of natural groupings or

breaks in the array as they appeared in Figures 1 to 5. Application of the chi-square test failed to show a significant fit of the segregations to a one, two or three factor Mendelian ratio, although the three factor ratio more nearly fits the available data than either the one or two factor ratios. In view of the above, it appears that a number of genes may be concerned with this type of blight inheritance. Although all populations were of the F_1 generation, their distributions differed. Variations in heterozygosity of parental varieties, as well as in size of the hybrid populations, probably accounted for these differences.

There appeared to be some dominance of resistance to susceptibility, although not consistent in all crosses. For example, in Nursery A, crossing the resistant Winesap with the susceptible Jonathan or Rome (see Figs. 1 and 2) produced a rather high proportion of resistant seedlings. However, in Nursery B, crossing the resistant Winesap with susceptible Rome or York resulted in considerably fewer resistant seedlings as shown in Fig. 4.

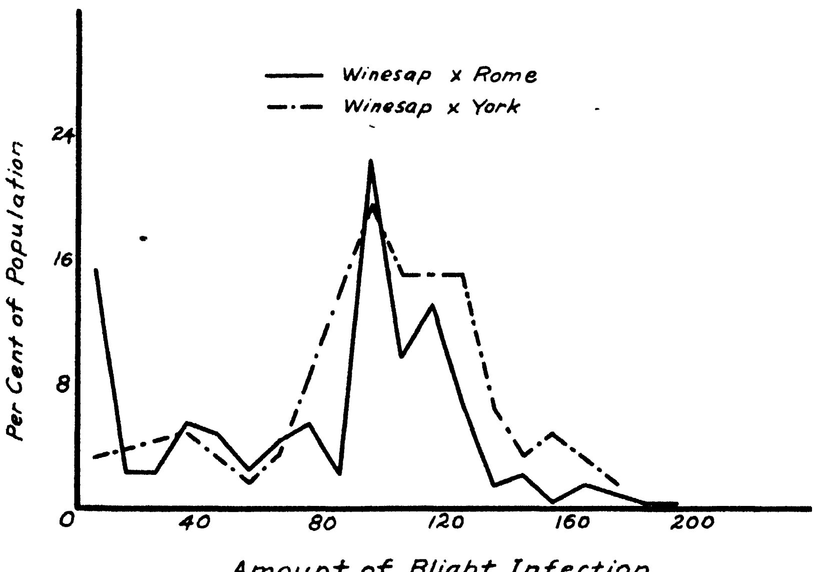

FIG. 4. Segregation for resistance to fire blight in 3-year-old hybrid apple populations showing least resistance.

Thomas and Ark (5) have found, in studying the progeny of a hybrid of *Pyracantha augustifolia* and *Pyracantha Gibbsii yunnanensis*, that resistance to fire blight seemed to be at least partially dominant to susceptibility.

The following factors are recognized as having a possible bearing upon the interpretation of results: (a) Populations were relatively small with no F_2 or F_3 generations or selfings available as customarily are considered desirable in a genetic study of this kind; (b) no cultural strain of the blight organism was used for the inoculation; (c) artificial inoculations automatically eliminated any genetic factor con-

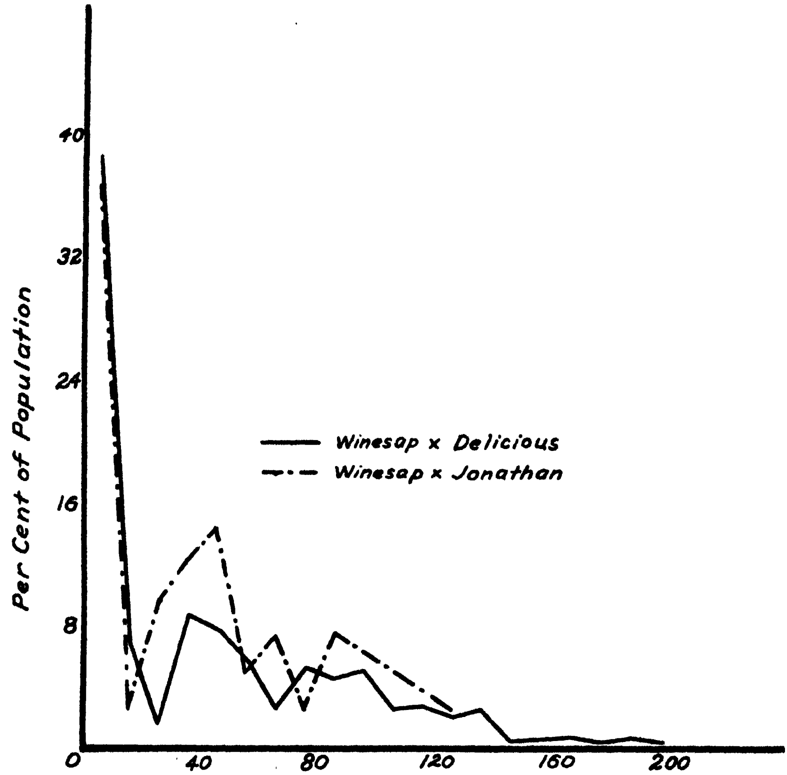

FIG. 5. Segregations for resistance to fire blight in 3-year-old hybrid apple populations showing greatest resistance.

cerned with entrance of the organism into the apple tissue; (d) seedlings of the Winesap x Jonathan and Jonathan x Rome crosses grew on slightly higher elevations than any others. The last factor, however, probably had no effect since the former displayed blight resistance; the latter susceptibility.

SUMMARY

Eighteen hundred and seventy-five 3- and 4-year-old F_1 hybrid apple seedlings obtained from 14 controlled crosses were artificially inoculated with the fire blight organism, *Erwinia amylovora* (Burr.) Wins., *et al.* A study was made of the genetic distribution of the populations into resistant and susceptible classes.

Analysis of the data indicated that all except three populations segregated significantly into blight resistant and susceptible classes. As a satisfactory criterion for determining whether or not there was segregation, the two most severely blighted shoots of each tree were used. A division point was assumed one inch from the annual ring in the direction of the tip. Trees, upon which blight injury of both shoots extended no farther than this division point, were classified as re-

sistant; if blight injury extended beyond this division point trees were classed as susceptible.

When the data were shown graphically it became apparent that the most resistant progenies are indicated to be those of Winesap x Delicious, Winesap x Jonathan, and Arkansas Black x Delicious. Least resistance was indicated by progenies of Melon x Jonathan, Melon x Lowry, Jonathan x Rome, and Winesap x York.

It appeared from these analyses that a number of genes may be concerned in this type of blight inheritance. While data failed significantly to fit one of the Mendelian ratios, they suggested that three, or perhaps more, factors were involved. Although all populations were of the F_1 generation, as a group their distributions resembled those of an F_2 generation. Probably the heterozygosity of the parent varieties, together with the varying size of the hybrid populations, chiefly accounted for the differences between the distributions of the populations.

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Blossom Hardiness of Forty-five Apple Varieties[1]

By E. M. MEADER and C. H. BLASBERG, *Vermont Agricultural Experiment Station, Burlington, Vt.*

THE unseasonably warm weather of March and April, 1945, forced apple flower buds at Burlington, Vermont, into active growth, and subsequent freezing temperatures caused varying amounts of injury, particularly among the different varieties growing in the College orchard. Since many varieties listed herein will not be maintained longer in a variety collection, this record is being made of their observed bud hardiness to cold injury during the spring of 1945.

The U. S. Weather Bureau station adjoins the college orchard. Its records showed only four minima below freezing from March 14 to April 14; they were 29.3, 30.8, 29, and 30.2 degrees F respectively on March 23, March 25, April 6 and April 7. The mean daily departure from normal temperature for March was plus 10.5 and for April, plus 6.3 degrees. By April 14, most buds had advanced to a tight cluster stage and some were at more advanced stages of development. On April 15 and 16, minima of 25.3 degrees and 25 degrees were recorded when some injury may have occurred. Warm days and nights without freezing temperatures prevailed until April 23, when a temperature of 23.9 degrees occurred, and it was followed by a recorded temperature of 27.8 degrees on the 24th. No reading below 30 degrees F was made after this last date for the remainder of the spring season. By April 21 the center flowers of the McIntosh were open. Full bloom for this variety, however, did not come until May 7. Northern Spy, a late blooming variety, reached full bloom May 15.

During the first week in May, 25 blossoming spurs were gathered at random at a height of about 6 feet from a tree of each variety. Examination showed plainly the cold injury that had occurred to the pistils earlier in April. Only uninjured pistils had enlarged and developed a normal green color. Few flowers having a normal green pistil and with browning in the vicinity of the ovaries were noticed, but damage to one or more of the stamens was common in some flowers that were otherwise unhurt by cold. Percentages given in Table I refer to the condition of the pistils and ovaries. Browning of petals and slight injury to the stamens do not preclude the flower from setting fruit.

RESULTS AND DISCUSSION

From data Table I it is apparent that most varieties in the McIntosh group are somewhat more tolerant of cold than is Delicious, a variety that is commonly planted with McIntosh for a pollinator. Some varieties which showed varying percentages of live flowers are characteristically late in flowering: Northern Spy, Red Spy, Rome Beauty, Macoun, Golden Delicious, Sweet Delicious, Sweet McIntosh, and French Crab. Such late flowering may have been a factor in their escaping injury that abounded in an earlier flowering sort such as

[1]A contribution from the Vermont Agricultural Experiment Station, published with the approval of the Director, December 10, 1945.

TABLE I—1945 SPRING COLD INJURY TO APPLE BLOSSOMS AND SUBSEQUENT FRUIT SET IN COLLEGE ORCHARD AT BURLINGTON, VERMONT

Group	No. Live Center Blossoms in 25 Clusters	Per Cent of Total No. of Flowers Alive	No. of Clusters Having One or More Live Buds Per Cluster	Fruit Crop
McIntosh Group				
McIntosh	15	76	24	Good
Hume	11	75	25	Heavy
Dark Red McIntosh	8	66	25	Good
Blackmack	7	65	25	Good
Blushed McIntosh	13	64	21	Good
Kendall	5	59	25	Good
Joyce	6	59	24	Light
Stonetosh	7	55	22	Good
Milton	7	52	22	Heavy
Cortland	2	52	25	Good
Macoun	4	50	21	Heavy
Patricia	11	50	20	Heavy
Diana	7	49	23	Light
Lobo	3	43	23	Light
Melba	0	41	20	Heavy
Lawfam	1	37	19	Light
Sweet McIntosh	2	31	14	Light
Delicious Group				
Delicious	0	5	4	3 apples
Richared	0	10	9	10 apples
Red Delicious	0	24	18	Light
Medina	0	27	17	Light
Starking	1	37	22	1 apple
Sweet Delicious	5	65	25	Light
Miscellaneous				
French Crab	23	99	25	Heavy
Tolman	13	88	25	Heavy
Sutton	13	79	25	Good
Red Spy	12	77	25	Good
Rome Beauty	10	68	25	Good
Wealthy	—	67	25	Heavy
Northern Spy	8	66	23	Good
Lawver	4	65	24	Heavy
Northwestern Greening	11	61	23	Light
Golden Delicious	9	59	22	Heavy
Yellow Transparent	7	57	23	Heavy
R. I. Greening	4	56	22	Light
Fireside	12	54	21	Heavy
Ranier	4	48	22	Light
Bottle Greening	8	47	20	Good
Haralson	5	40	18	Heavy
Black Fameuse	2	35	17	Light
Baldwin (small trees)	2	33	19	Light
Minn. 790	0	33	15	Light
Linda	1	23	12	Light
Red Gravenstein	2	17	14	Light
Wolf River	0	9	9	——

Delicious. Burrell and Boynton (1) have shown that during the spring of 1945, the buds of McIntosh that had received high applications of nitrogen for 3 years were more susceptible to cold injury than unfertilized McIntosh trees. Differential nitrogen levels also may have been a factor in this study, but their effects on varieties could not be easily ascertained. Appreciable differences in orchard elevation were thought to have had a minimum effect due to wind that prevailed during the coldest night.

As has been noted many times by others, good crops of fruit set on trees that had had large percentages of their flowers cold injured. For example, Melba, which had 41 per cent, and Haralson, with 40 per cent live flowers, both set so heavily that their fruit required thin-

ning to develop good size. It is of interest that all center blossoms of Melba had been killed. Using the number of clusters out of a possible 25 that had one or more live buds to the cluster as a criterion for crop prospects of a variety, only Delicious and its bud sport, Richared, were thought of as a crop failure early in the season. Data on the crop of fruit harvested showed that another bud sport of Delicious, Starking, should be added to the list of varieties having a crop failure.

In fact, numerous observations in many Vermont McIntosh orchards indicated that greater crop losses occurred during May, 1945, from lack of adequate pollination during rainy inclement weather when bee activity was limited than in April when freezing injury to some flower buds is known to have occurred.

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Cold Injury of Apple Blossoms, 1945[1]

By R. H. ROBERTS, *University of Wisconsin, Madison, Wis.*

THE unusually early start of growth, prolonged blossoming period and recurring freezing temperatures in the spring of 1945 gave an opportunity to observe the effect of cold upon blossoms in different stages of development of several varieties of apples. Injury to the ovules (and pistils) was the type recorded.

Wealthy blossom buds reached the green-tip stage at Madison, March 31, 3 to 4 weeks earlier than average. Full blossom was recorded

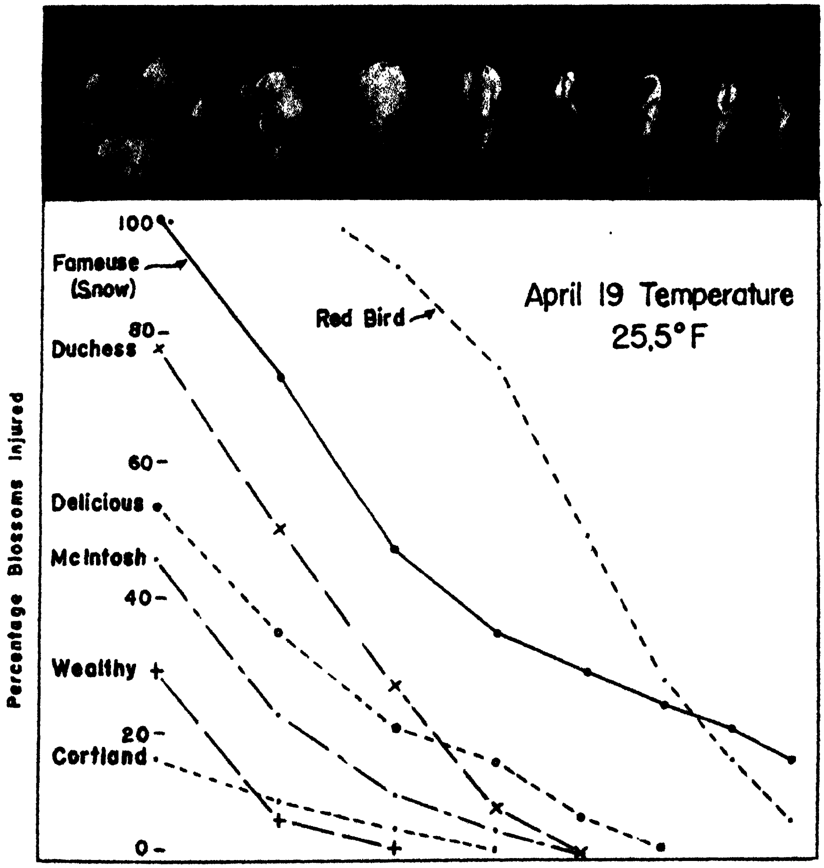

FIG. 1. Graphs showing the percentage of blossoms with injured ovules at different stages of development, as shown at top. Jonathan and Dudley suffered approximately the same amount of injury as Delicious on April 19. Only Cortland remained relatively hardy through both deep freezes. Wealthy and Jonathan produced a fair crop because of their characteristic late development of axillary blossom buds.

[1]Published with permission of the Director of the Agricultural Experiment Station.

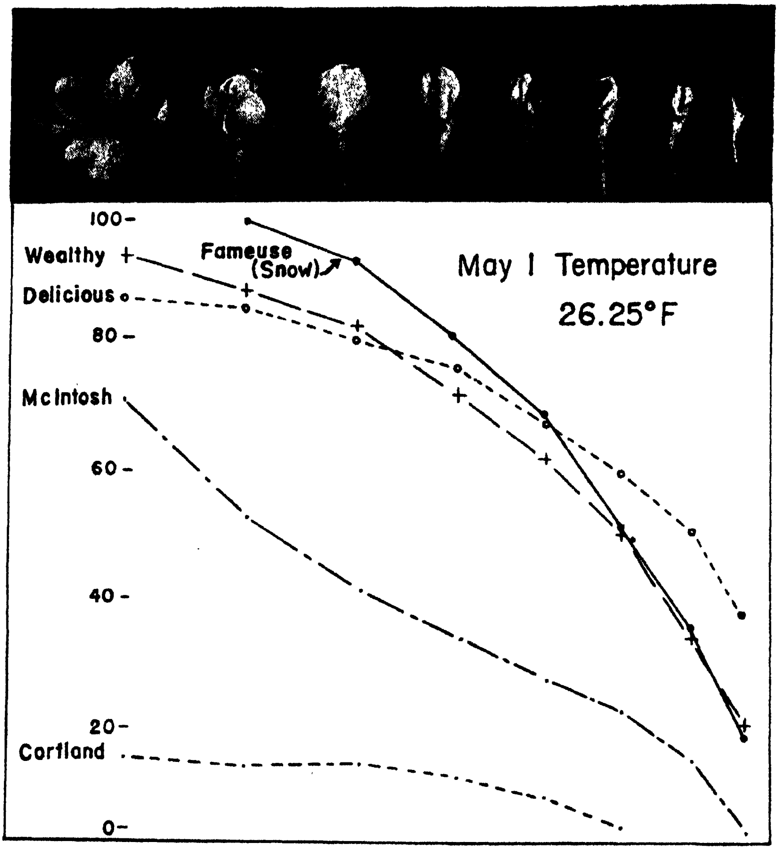

FIG. 2. Graphs showing injury after second freeze on May 1.

as from April 30 to May 6, about 10 days earlier than usual.

In the period from April 4 to May 10, temperatures below freezing were recorded by a minimum thermometer in the University orchard on 12 nights. On April 19, a low temperature of 25.5 degrees F was reached 2 feet above the ground. A recording thermometer showed the temperature was below 32 degrees for 7 hours and below 30 degrees for 4½ hours. It was below 28 degrees for somewhat less than 2 hours. The amount of blossom injury on the branches below 7 feet is recorded by the upper graphs of Fig. 1.

On May 1, a low of 26.25 degrees was recorded. The temperature was below 32 degrees for approximately 4 hours, below 30 degrees for 3 hours, and below 28 degrees for about 1 hour. The injury to ovules is shown by the graphs of Fig. 2.

The graphs show that there was a marked decrease in hardiness as full blossom stage is approached; also a great difference in varietal susceptibility. They also show that there was an increase in tenderness of the varieties observed, except Cortland, in the 12 days since the

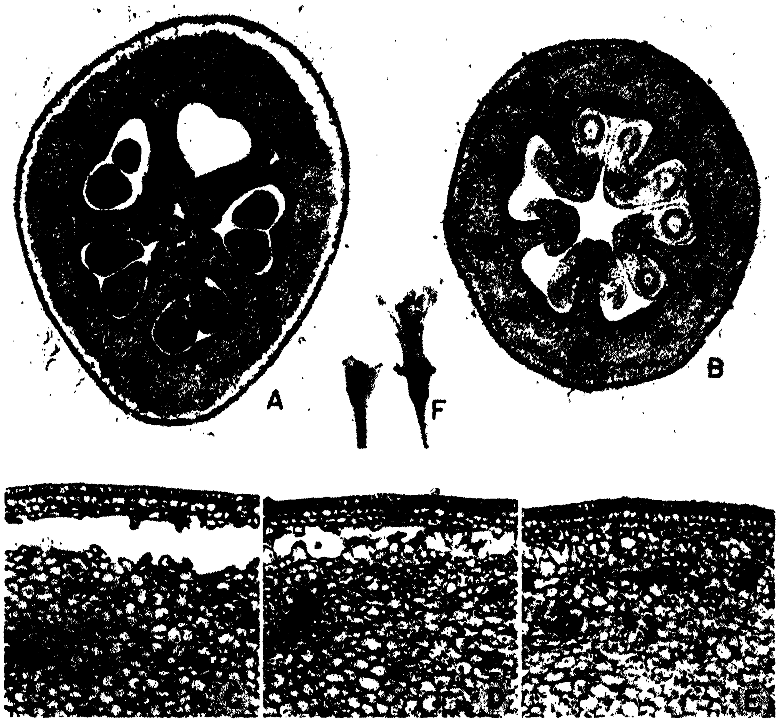

FIG. 3. Nature of frost injury to Wealthy receptacles April 19. A and C— loose epidermal layers April 21. B and E —after 48 hours in a warm greenhouse. Apparently the loose layer of cells contracted to meet the toral tissue and proliferating cells are establishing callus contact. D—"healing" after 24 hours in greenhouse. F—"skin" slipped from receptacle and peduncle. The mature apples showed practically no "frost bands" or characteristic russet attributable to cold injury. Microscopic preparations and photographs by Dr. B. E. Struckmeyer.

previous deep freeze (Fig. 1). There was a marked change in the susceptibility of Wealthy.

In addition to ovule injury, it was noted on May 20 that the epidermis was loose on the receptacles of all blossoms examined within 6 feet of the ground (Fig. 2, F). When branches with blossoms were removed to the greenhouse, the "skins" had tightened very appreciably over night or in 15 to 16 hours and were apparently tight the second day (Fig. 3, B, E). A similar tightening occurred in the orchard with the advent of growing temperatures.

A like condition has been recorded by Dorsey (1) who reviews his observations and those of other workers.

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Tolerance of Apple Varieties to Methyl Bromide Fumigation[1]

By A. L. KENWORTHY, *University of Delaware, Newark, Del.* and C. H. GADDIS, *U. S. Department of Agriculture, Trenton, N. J.*

THE apple growers in Delaware suffered considerable loss in 1944 as a result of fumigation of Williams apples with methyl bromide for Japanese beetle control. Since Williams was very sensitive to methyl bromide, it seemed desirable to test the tolerance of other varieties to the fumigant. The tolerance tests included 20 varieties in 1944 and 13 in 1945.

Phillips, Monro, and Allen (1), Phillips and Monro (2), and Chapman (3) observed injury to McIntosh when fumigated with methyl bromide. Phillips and Monro (2) reported that Delicious, Stark, Ben Davis, Rhode Island Greening, and Baldwin showed no injury when fumigated with methyl bromide. Kenworthy (4) found Williams to be susceptible to methyl bromide injury while Starr and Wealthy showed no injury under conditions of the test.

PROCEDURE

Samples of the fruit were obtained direct from the grower after the fruit had been prepared for market. The fruit was divided into three lots of 100 apples each and fumigated as quickly as possible. The treatments were: (1) Two pounds of methyl bromide per 1000 cubic feet; (2) three pounds of methyl bromide per 1000 cubic feet; and (3) check. After being fumigated at room temperatures, which ranged between 65 and 70 degrees F in 1944, and 50 to 75 degrees F in 1945, the fruit was held in common storage for 10 days with observations at 5-day intervals.

DESCRIPTION OF INJURY

The injury was classed as surface injury, initial internal injury, and advanced internal injury. The symptoms varied with the variety, and no clear description can be made for all. No variety showed symptoms entirely like those reported by Kenworthy (4).

Surface injury was considered as any scald or breakdown originating on or at the surface of the fruit. Initial internal injury was any breakdown or discoloration involving small areas near the carpel wall or in the core of the fruit. Advanced internal injury consisted of any breakdown or discoloration occurring in the flesh of the fruit involving areas greater than ¼ inch in diameter.

OBSERVATIONS — 1944

McIntosh, Stark, Cortland, Jonathan, Grimes, Gallia Beauty, Blaxtayman, Paragon, Golden Delicious, Rome Beauty, Lily of Kent, Stay-

[1]Published as Miscellaneous Paper No. 14 with the approval of the Director of the Delaware Agricultural Experiment Station. Contribution (No. 5) of the Department of Horticulture.

man, Gano, Winesap, and Nero showed no injury resulting from fumigation within 10 days after treatment.

Wealthy showed 2 per cent advanced internal injury 10 days after a treatment of 2 pounds of methyl bromide per 1000 cubic feet and 8 per cent when treated with 3 pounds per 1000 cubic feet. Most of the injury recorded for Wealthy consisted of an advanced breakdown occurrring mainly at stem punctures. The breakdown proceeded from the skin inward.

Fourteen per cent advanced internal injury developed when Starking was treated with 2 pounds per 1000 cubic feet and 26 per cent when treated with 3 pounds per 1000 cubic feet. The cores of these fruits were infected with Alternaria rot. This rot was also present in the injured flesh near the core.

The only injury showed by Delicious was 4 per cent surface scald when treated with 3 pounds per 1000 cubic feet. The fruits of Delicious did not have Alternaria rot in the core. The lack of advanced breakdown in Delicious and its abundance in Starking indicate a close relationship between the presence of Alternaria rot and advanced breakdown. This association may be due to the effect of methyl bromide upon the rate of ripening of the fruit.

Orleans developed 4 per cent advanced internal breakdown 5 days after a treatment of 2 pounds per 1000 cubic feet and 10 per cent when treated with 3 pounds. The amount of injury was slightly less 10 days after treatment. The fruits of this variety were free of Alternaria rot.

Methyl bromide produced surface scald on York Imperial. A 2-pound treatment resulted in 8 per cent scald, while 14 per cent scald developed as a result of the 3 pound treatment. The scald on York Imperial had the same characteristic pattern observed on Williams (4). There was no scald present when observations were made 5 days after treatment.

Observations — 1945

Of the varieties tested in 1945, Cortland, Jonathan, Starking, Blaxtayman, Rome, Gallia Beauty, and Lily of Kent showed no injury when fumigated with methyl bromide.

Considerable surface injury developing near the stem and advanced internal breakdown were found on Wealthy. Both surface injury and internal injury were observed 5 days after treatment, and the injury was more prevalent when observed 10 days after treatment. Ten days after treatment there was 26 per cent surface injury and 8 per cent advanced internal injury on fruits treated with 2 pounds of methyl bromide. Following treatment with 3 pounds, there was less injury than occurred in the 2-pound treatment. The Wealthy checks, however, showed 2 per cent surface injury within 5 days, and 8 per cent within 10 days. This indicates that the injury recorded was due to some rot organism and that methyl bromide fumigation caused a more rapid spread of the organism by increasing the rate of ripening of the fruit. The advanced internal injury recorded, however, was not present in the check lot and must be attributed to methyl bromide.

McIntosh showed 2 per cent surface injury when treated with 2 pounds of methyl bromide and 4 per cent when treated with 3 pounds.

Six per cent internal injury developed within 10 days after fumigation with 3 pounds of methyl bromide. The flesh of the fumigated fruit often acquired a bright pink color.

The internal injury found in Delicious after fumigation was small in size but present in 16 to 24 per cent of the fumigated fruit. The checks showed up to 4 per cent of a similar injury. As with the surface injury of Wealthy, this injury may be a result of a rot organism developing more rapidly because of the ripening effect of methyl bromide upon the fruit.

Surface scald on York Imperial after fumigation was much less in 1945 than in 1944. Only 4 per cent scald developed within 10 days after fumigation with 3 pounds of methyl bromide per 1000 cubic feet. The scald spots were typical, as in 1944.

Only initial internal injury was observed on Orleans. After fumigation with 2 pounds of methyl bromide, there was 8 to 10 per cent initial internal injury, while 30 to 40 per cent of the fruit developed internal injury in the 3-pound lot.

Grimes developed 5 per cent initial internal injury within 5 days after fumigation with 3 pounds of methyl bromide and 12 per cent within 10 days. No injury was observed in the 2-pound lot.

Summary

As a result of studies conducted in 1944 and 1945, the following varieties appear under Delaware conditions to be subject to injury or earlier decay when fumigated with methyl bromide: Wealthy, McIntosh, Delicious, York, Grimes, and Orleans. Of these varieties Wealthy, Delicious, York, and Orleans appear to be more susceptible to methyl bromide injury than McIntosh and Grimes.

No injury occurred on Cortland, Jonathan, Starking, Blaxtayman, Rome, Gallia Beauty, Lily of Kent, Stark, Paragon, Gano, Winesap, or Nero.

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Some Factors Affecting the Brown Core Disease of McIntosh Apples

By R. M. Smock, *Cornell University, Ithaca, N. Y.*

Introduction

Brown core of apples constitutes a major source of waste in storage with certain varieties. It is also called "core browning" and "core flush." The main characteristic of this disorder is that the flesh turns brown near the core. Its first appearance is noted as a slight discoloration between the seed cavities. Later considerable portions of the flesh around the core become rather brown. There is no sharp line of demarcation between healthy and affected portions of the flesh. These large brown areas seriously detract from the market value of the fruit.

In New York this physiological disorder is particularly severe on McIntosh but may occur on Rhode Island Greening, Twenty Ounce, or Baldwin. One usually sees first sign of the trouble in December and it becomes progressively worse in storage.

There are other internal disorders of the apple that might be confused with brown core. Certain apples affected with cork disease resulting from boron deficiency have symptoms similar to brown core. With cork the flesh is dry and rather flaky whereas in brown core the affected flesh is moist and rather firm. The early stages of mealy breakdown in a variety like Northwestern Greening look very much like brown core. Another trouble that turns the flesh of the apple brown is internal browning but with this trouble the affected brown areas are not confined to the core but radiate from the core clear out to the skin.

Effect of Orchard Treatments on Brown Core

Defoliation, Limb, and Fruit Shading:—While brown core is specifically a storage disorder, its intensity varies considerably from year

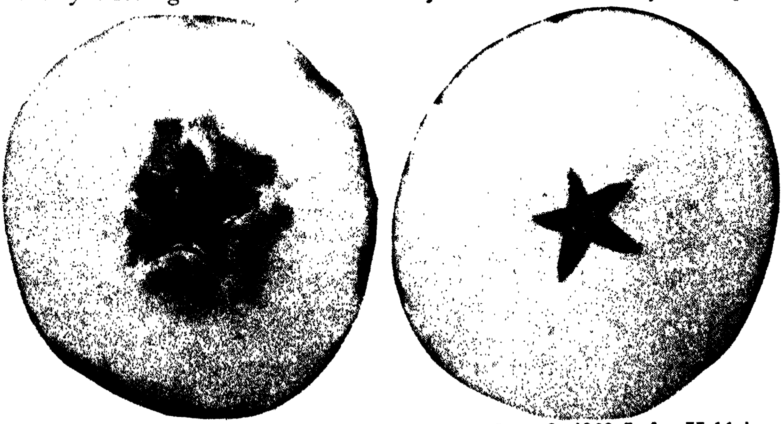

Fig. 1. McIntosh apples removed from storage June 2, 1939 Left: Held in air at 32 degrees F (showing severe brown core) Right: Held in 5 per cent carbon dioxide and 2 per cent oxygen at 40 degrees F.

to year. This would indicate that certain climatic or other environmennental factors must influence susceptibility to the trouble.

In an attempt to influence susceptibility in McIntosh to brown core, individual limbs of several trees in the same orchard were treated for 3 years. Different trees were used each year lest the limb treatments have a residual effect the following year. The trees were about 15 years old at the start of the treatment and were in moderate vigor. They were growing in sod culture.

All limb treatments were made in late June or early July of each year. Large individual limbs were shaded with three layers of cheesecloth. This treatment is called "limb shaded." Similar limbs on each tree were defoliated. Individual fruits were covered with white waxed paper. This last treatment would presumably lower temperatures of the fruit and reduce the light intensity reaching the fruit during the sunlight hours.

The shaded fruits (whether "limb" or "fruit" shaded) developed but very little red coloration. The fruits on the defoliated limbs had normal size and were highly colored since the limbs were not ringed.

The fruits were harvested at the optimum time for picking and were stored at 32 degrees F. They were examined for brown core in late April or early May of each year.

The results of these treatments appear in Table I. It is clear from the results that limb shading with cheesecloth consistently increased susceptibility to brown core. Fruits which were individually shaded with white paper showed variable results but on the average there was little or no effect. The significant thing is that this did not increase the amount of brown core as did limb shading. Defoliation seemed to have no significant effect.

TABLE I—INFLUENCE OF DEFOLIATION, LIMB SHADING, AND FRUIT SHADING ON BROWN CORE IN McINTOSH

Treatment	Average Per Cent Brown Core on All Trees*		
	1941–42	1942–43	1943–44
Control	0.31 ±0.469	34.78 ±6.43	17.45 ±3.01
Defoliated	0.00 ±0.0	———	15.24 ±4.42
Limb shaded	27.40 ±10.75	70.73 ±1.94	56.28 ±4.48
Fruit shaded	———	29.04 ±2.74	18.74 ±3.21

*1941–42—4 trees used. 1942–43—5 trees used. 1943–44—6 trees used.

Effects of Nitrogen Fertilization:—An experiment was conducted in the Cornell orchards during 1941–42 and 1943–44 to test the effects of summer applications of nitrogen. This 15 year old orchard was in a state of very low vigor and was growing in sod. Applications of 5 pounds of Uramon (42 per cent nitrogen) were made to each treated tree in July. No treatments were made in 1942 because of the small crop. The nitrogen treated trees showed a marked response to the fertilizer treatment. There were darker green leaves and less highly colored fruit. The apples were stored at 32 degrees F and examined in early May each year.

Since only 5 trees were treated over a period of only 2 years the

experiment is of only limited value and can only supplement the more complete study previously reported upon (6).

TABLE II—EFFECT OF SUMMER NITROGEN TREATMENT ON BROWN CORE IN McINTOSH

Treatment	Average Per Cent Brown Core in Fruit from All Trees*	
	1941-42	1943-44
Control	0.16 ±0.10	8.04 ±3.48
Nitrogen	2.90 ±1.09	18.58 ±5.02

*5 trees in each treatment.

There is a suggestion in Table II of increased brown core susceptibility with nitrogen applications although the differences are not large.

EFFECT OF PRE-STORAGE FACTORS ON BROWN CORE

Fruit Maturity:—It has been previously reported (1, 4) that fruit picked in an immature condition was more susceptible to brown core. However, Smith (5) has stated that in years of heavy incidence of brown core that late picking had little effect in reducing the amount of this trouble.

In this experiment one bushel samples of fruit were harvested from each of the same six trees over a period of 3 years. The fruit was stored at 32 degrees F and examined for brown core early in May. Fruit was picked on the same calendar dates each year but, of course, varied in actual maturity from year to year on those dates.

The results in Table III indicate that susceptibility to brown core decreases as apples mature on the tree. In a year of extreme susceptibility even the last picked apples may have considerable brown core.

TABLE III—INFLUENCE OF DATE OF PICKING ON BROWN CORE IN McINTOSH

Harvest Date	Per Cent of Brown Core		
	1941–42	1942–43	1943–44
Sep 3	12.0	100.0	78.00
Sep 10	10.0	88.89	36.00
Sep 17	2.0	95.70	18.50
Sep 24	0.0	37.03	32.00
Oct 1	0.0	31.14	14.00
Oct 8	0.0	30.61	26.00

Effect of Delayed Storage:—One bushel lots of McIntosh were stored immediately at 32 degrees F after harvest or were delayed for 5, 10, 15 and 20 days. During the period of delay the apples were held on the packing house floor. The apples were examined for brown core April 20, 1938 and March 28, 1939.

The results in Table IV indicate that while brown core may be lessened by delays in storage that some brown core may be experienced in some years in the fruit with even the longer delay periods. Even a 5-day delay period takes enough off the storage life of this

TABLE IV—EFFECT OF DELAYED STORAGE ON BROWN CORE IN McINTOSH

Treatment	Per Cent Brown Core	
	1937–38	1938–39
Immediate storage	84	66.6
5 days delay	42	44.0
10 days delay	—	37.0
15 days delay	8	35.0
20 days delay	—	11.6

variety that the fruits should be sold by Christmas. Brown core seldom becomes severe in immediately stored fruit until after that time.

STORAGE FACTORS INFLUENCING BROWN CORE

Storage Temperature:—It has been known for sometime (1, 2, 4) that brown core was a low temperature storage disorder. That is, it is more prevalent when the fruits are stored at 32 degrees F than when held at higher temperatures. Table V which includes the effect of various storage temperatures also indicates seasonal variations in this trouble over a period of 7 years. The apples were removed from storage in May or early June for examination each year.

TABLE V—EFFECT OF STORAGE TEMPERATURE ON BROWN CORE IN McINTOSH

Storage Temperature (Degrees F)	Per Cent Brown Core						
	1937–38	1938–39	1940–41	1941–42	1943–43	1943–44	1944–45
32	—	90.0	100.0	30.0	73.0	36.0	52.0
36	20.0	30.0	—	—	—	—	—
40	0.0	0.0	14.0	0.0	8.0	0.0	0.0

It is clear from Table V that brown core is much more severe at 32 degrees F than at 40 degrees F. In 1938–39 the apples held at 36 degrees F were intermediate in their amount of brown core between those stored at 32 degrees F and 40 degrees F. Fluctuations in susceptibility from year to year may also be noted in Table V.

Effect of Carbon Dioxide and Oxygen Levels:—Various carbon dioxide and oxygen levels were examined as to their possible effects

TABLE VI—EFFECT OF DIFFERENT CARBON DIOXIDE AND OXYGEN LEVELS ON BROWN CORE OF McINTOSH (1937–38)

Temperature (Degrees F)	Carbon Dioxide (Per Cent)	Oxygen (Per Cent)	Brown Core (Apr. 29, 1938) (Per Cent)
36	0*	21	20.0
40	0*	21	0.0
40	5	16	0.0
40	10	11	27.5
40	15	6	85.0
40	3	4	0.0
40	5	6	0.0
40	5	2	0.0

*Air.

on brown core since some low temperature troubles are accentuated by high levels of the former.

During the 1937–38 season McIntosh were held in various oxygen and carbon dioxide levels at 40 degrees F in controlled atmosphere storage. The results appearing in Table VI indicate a suggestion of increased brown core with higher carbon dioxide levels when the oxygen percentage is 6 per cent or higher at 40 degrees F. Since the oxygen percentages were not all the same this finding is only suggestive.

During 1938–39 McIntosh apples were held in various oxygen and carbon dioxide levels at two temperatures. It is apparent in Table VII that at 36 degrees F there seemed to be the least brown core with low carbon dioxide and a low oxygen level. The only brown core occurring at 40 degrees F was with 10 per cent carbon dioxide with 11 per cent oxygen.

TABLE VII—Effect of Different Oxygen and Carbon Dioxide Levels on Brown Core in McIntosh (1938–39)

Temperature (Degrees F)	Carbon Dioxide (Per Cent)	Oxygen (Per Cent)	Brown Core (June 2, 1939) (Per Cent)
32	0*	21	90.0
36	0*	21	30.0
36	5	16	30.0
36	10	11	30.0
36	2	2	0.0
36	5	2	55.0
40	0*	21	0.0
40	10	11	30.0
40	10	2	0.0
40	5	5	0.0
40	5	2	0.0

*Air.

During the 1941–42 season McIntosh were stored at various carbon dioxide levels with the oxygen at 2 per cent in all cases. In one series the carbon dioxide level was held at 5 per cent for 1, 2, 3 and 4 months and then it was increased to 10 per cent. Data are not presented but it was evident that there was no brown core in any lot of fruit during this season in this experiment. Perhaps no brown core was experienced because only low oxygen levels were used; at any rate it is clear that a range in carbon dioxide up to 10 per cent had no effect on brown core when a low oxygen level was used at 32 degrees F and 40 degrees F.

During the 1942–43 season the previous experiment was repeated with regard to carbon dioxide effects at 40 degrees F. The fruit held in air at 32 degrees F developed 73.3 per cent brown core whereas that held in 2 per cent oxygen with 5 per cent carbon dioxide had only 13.3 per cent. At 40 degrees F there were no effects of carbon dioxide in the range of 0–10 per cent on brown core with a 2 per cent oxygen level.

During the 1944–45 season different oxygen and carbon dioxide levels were again tested as to their effect on McIntosh brown core. Table VIII indicates that at 32 degrees F there was less brown core

TABLE VIII—EFFECT OF DIFFERENT OXYGEN AND CARBON DIOXIDE LEVELS ON BROWN CORE IN McINTOSH (1944–45)

Temperature (Degrees F)	Carbon Dioxide (Per Cent)	Oxygen (Per Cent)	Brown Core Apr. 10, 1945 (Per Cent)
32	0*	21	52.0
32	5	2	6.0
32	10	2	14.0
40	0*	21	0
40	5	10	0.0
40	10	10	0.0
40	15	10	32.0
40	5	2	0.0
40	10	2	0.0

*Air.

at low oxygen (2 per cent) than in air. At 40 degrees F there was no brown core except where 15 per cent carbon dioxide was used with a relatively high oxygen level (10 per cent).

Since it had been shown in previous years' work that there was a suggestion of more brown core with increasing quantities of carbon dioxide only when the oxygen level was high, an experiment was set up during the 1945–46 season to further test this point. Twenty per cent oxygen was maintained with varying carbon dioxide levels. The results may be seen in Table IX.

TABLE IX—EFFECT OF DIFFERENT OXYGEN AND CARBON DIOXIDE LEVELS ON BROWN CORE IN McINTOSH (1945–46)

Temperature (Degrees F)	Carbon Dioxide (Per Cent)	Oxygen (Per Cent)	Brown Core (March 9, 1946) (Per Cent)
32	0*	21	12.00
32	5	20	0.00
32	10	20	33.33
40	0*	21	0.00
40	10	20	30.00

*Air.

The results of this experiment tend to confirm those conducted in previous years. The only discrepancy in the data is the absence of brown core with 5 per cent carbon dioxide and 20 per cent oxygen at 32 degrees F. There seems to be additional evidence here that increasing the carbon dioxide level when the oxygen level is high will increase the amount of brown core at 40 degrees F. The effect at 32 degrees F is not clear.

DISCUSSION

It has been shown in this study and in other investigations (3, 4) that the intensity of brown core in McIntosh varies considerably from season to season. Smith (4) attributed greater susceptibility in some years to higher rainfall and somewhat lower temperatures during the growing season. In this study it has been shown that limb shading greatly increased susceptibility to this trouble. This result of shading may have been due to lower temperatures or lower light intensity or both. Shading of individual fruits did not increase susceptibility, so it seems apparent that climactic effects on the leaves are of some im-

portance in determining the amount of brown core experienced in storage. Defoliation, however, seemed to have no effect on brown core.

In a previous study (6) involving five orchards it was shown that if sufficient nitrogen was added to affect the leaf nitrogen content that brown core susceptibility was often increased. Some supplementary data is given in this report to substantiate this finding, although the effects were not large. Smith (4) has reported that in years of light incidence of brown core that heavy applications of nitrogen increased susceptibility. In years of extreme susceptibility he found no differences as a result of nitrogen fertilizer applications. These accumulated findings would indicate that heavy nitrogen applications may have some influence on brown core incidence, particularly in some years.

This study and others (3, 4) have shown that the riper the fruits when harvested the less the brown core experienced in storage. This finding may throw some light on the nature of susceptibility but is of no practical benefit. If the apples are picked ripe enough to escape brown core they would be too mature for long keeping. In 2 out of 3 years 25 per cent or more of the fruit picked even as late as the first week in October had brown core.

Still other orchard factors than those reported upon here may be effective in determining susceptibility to brown core. Work in New Zealand by Tiller and Padfield (7) indicates that core flush (brown core) in Granny Smith apples may be affected by the rootstock. It was worse in apples grown on Northern Spy rootstock than on the East Malling stocks. An intermediate stem piece of Reinette Du Canada seemed to confer resistance in the scion variety.

Rasmussen (3) suggested that a delay in storage for 5 days after harvest might be employed to escape brown core. He recognized the fact that there delayed storage fruits would not keep as long in storage as immediately stored fruits from the standpoint of firmness. A study of delayed storage in this investigation showed that delayed storage might materially reduce this trouble but that it certainly did not result in prevention of it. In 1 year (1938–39) fruits delayed in storage as long as 15 days had 35 per cent brown core. This practice would not seem to hold very much promise as a commercial control of this disorder.

Other studies (1, 3) have shown as well as this one that brown core is a low temperature disorder. It is much more prevalent when the apples are stored at 30 to 32 degrees F than when they are stored at higher temperatures. Storage at 40 degrees F in controlled atmosphere storage would seem to be the most practical method of avoiding this trouble and yet keeping the apples in firm condition (5).

Results in this study of the effect of various carbon dioxide levels at different temperatures do not lead to entirely clear cut conclusions. It would seem clear at any rate that brown core is not a specific carbon dioxide injury at low storage temperatures as is brown heart (2). There is a suggestion of increased brown core in this study with increasing concentrations of carbon dioxide when fairly high oxygen levels are used. This was more noticeable at 40 degrees F than at 32

degress F. This browning of the flesh around the core at 40 degrees F with high carbon dioxide at relatively high oxygen levels may be a direct carbon dioxide injury which merely *resembles* brown core. That is, the resulting injury may have the same symptoms as the low temperature injury called brown core.

There is some evidence in this study to the effect that low oxygen atmosphere (2 per cent) result in less brown core at low storage temperatures (32 to 36 degrees F) than normal oxygen atmospheres (21 per cent).

Summary

Shading of individual limbs of the trees during the growing season increased susceptibility to brown core in storage. Shading of individual fruits and defoliation had no effect.

Supplementary data is offered to show that nitrogenous fertilizers may in some years increase susceptibility to brown core.

The more mature apples are picked, the less brown core they develop in storage. Delayed storage decreases susceptibility. Neither of these findings would seem to have any practical bearing on prevention of the trouble, however.

Further data is offered to indicate that this trouble is specifically a low temperature disorder and that susceptibility varies widely from year to year.

Brown core does not seem to be aggravated by high carbon dioxide concentrations at 32 or 36 degrees F although there was a suggestion of increased brown core at 40 degrees F with high carbon dioxide when relatively high oxygen levels were used. Low oxygen levels (2 per cent) definitely reduced the amount of brown core at 32 and 36 degrees F.

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Prevention of Sedimentation in Apple Juice Clarified by the Enzymic Method[1]

By Roy E. Marshall, *Michigan State College, East Lansing, Mich.*

The writer reported in 1943 (1) that concentrations of powdered, 140 grade apple pectin as low as 0.0055 per cent by weight (0.7 oz. per 100 gallons juice) in apple juice, subsequent to enzymic clarification and filtration but before flash pasteurization, prevented the formation of a conspicuous and unsightly amorphous precipitate in the bottom of juice packs some 2 to 6 months after packing when stored at normal room temperatures. The amount of accumulated air-dried sediment deposited on the bottom end covers of 20-ounce cans averaged 148 milligrams of air-dried materials for the controls and 25 milligrams for all treatments that contained added pectin.

Since the lowest concentration tried gave results as satisfactory as higher concentrations, further testing seemed desirable to attempt to find the minimum amount of pectin that could be recommended to accomplish practical results. Furthermore, it appeared that the liquid form of pectin would be more practical for use in commercial plants than the powdered material. Subsequent tests were therefore planned with apples of the 1943 crop to determine the minimum concentrations of both starch-free and non starch-free liquid pectins of approximately 50 grade that would provide satisfactory results.

Predetermined quantities of liquid 50 grade pectins to provide nine concentrations ranging from 0.12 to 0.88 per cent (1.5 to 112.7 ounces per 100 gallons juice) were added to No. 2 cans before filling with flash pasteurized juice that had previously been subjected to enzymic clarification and filtration in January of 1944. Two sets of controls were also packed. Each treatment consisted of five cans.

These cans of apple juice were stored at room temperature for approximately 6 months. They were then opened, the liquid decanted carefully, and the bottom end can covers removed. These bottom end can covers were allowed to dry in the laboratory for 24 hours, when they were weighed. The covers were then washed in running tap water, wiped dry, and allowed to dry for another 24 hours when they were reweighed. The differences between the net weights of materials adhering to the inside of bottom end covers of controls and the several treatments are assumed to represent the reductions in sediment accumulation due to the treatments.

Non-acidulated starch-free 50 grade, liquid, apple pectin used at the rate of 0.017 per cent (2.1 ounces per 100 gallons juice) reduced the weights of dry sediment to amounts that were significantly lower than those for the controls. Likewise, a concentration of 0.056 per cent (7.2 ounces per 100 gallons) gave significantly better results than 0.017 per cent and 0.113 per cent (14.4 ounces per 100 gallons) reduced the amount of sedimentation significantly below that obtained with the addition of 0.056 per cent liquid pectin. There was some reduction in

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amount of sedimentation when the amount of pectin exceeded 0.113 per cent but the reductions were not statistically significant.

Significant reductions in the amount of sedimentation following the addition of acidulated, non-starch free, apple pectin of approximately 60 grade were not obtained until the concentration amounted to 0.113 per cent (14.4 ounces per 100 gallons). Further significant reductions were obtained when the concentrations of this pectin were increased to 0.224 per cent (28.6 ounces per 100 gallons) and 0.44 per cent (56.4 ounces per 100 gallons), respectively. Thus, this form of pectin appears to be less effective in reducing sedimentation than the non-acidulated, starch-free kind.

Another set of treatments were packed February 14, 1945, in plain tin cans. Again, a blend of several varieties were used in preparation of this juice and the juice was subjected to enzymic clarification and filtration prior to the addition of the pectins. Twelve cans were packed for each of the 26 treatments. Some 7 months later the bottom can covers were removed from 10 cans of each lot to which the non-acidulated, starch-free, liquid pectin of 50 grade were added, allowed to dry, weighed, washed, and reweighed as in the previous year.

Even though the handling and processing treatments were apparently like those of former years, the control packs failed to produce substantial amounts of sedimentation, *i.e.*, the bottom end covers of controls were reasonably free from sediment. It had previously been observed that some lots of juice expressed and packed on successive days or weeks showed extreme variability in amounts of sedimentation even though no substantial differences in technique were evident. Even though there was little sedimentation in any of these lots, the numbers involved in each treatment permit an analysis of the results for significance and application to commercial operations.

The non-acidulated, starch-free liquid pectin used at a concentration of 0.019 per cent (2.5 ounces per 100 gallons) reduced the amount of sedimentation but the difference between this treatment and controls is of questionable significance. When the amount of this pectin equalled or exceeded 0.039 per cent (5 ounces per 100 gallons) the results were highly significant, but there were no significant gains resulting from concentrations greater than 0.039 per cent.

Lots to which the acidulated, non-starch-free pectin was added on February 15 were not opened until the following January, thus the storage period was approximately 11 months at room temperature. During this four-month additional storage period, the amount of sedimentation for the controls more than doubled in quantity.

The lowest concentration tested (0.039 per cent or 5 ounces per 100 gallons) reduced the amount of sedimentation substantially below that of the controls and each successively higher concentration (0.078, 0.117 per cent) gave significantly less sedimentation than the next lower concentration until the concentration reached 0.156 per cent (20 ounces per 100 gallons). Concentrations higher than 0.156 per cent failed to further reduce sedimentation.

Powdered pectin of 140 grade was also added to a few lots of juice

packed on February 15, 1945. If the additions of this powdered pectin are expressed in terms of concentration of 50 grade pectin, the results are almost identical with those reported for comparable concentrations of the non-acidual, starch-free, liquid pectin. In other words, there was no significant gain due to addition of more than the equivalent of a 0.035 per cent concentration of 50 grade liquid pectin and a concentration of 0.018 per cent was significantly better than the control.

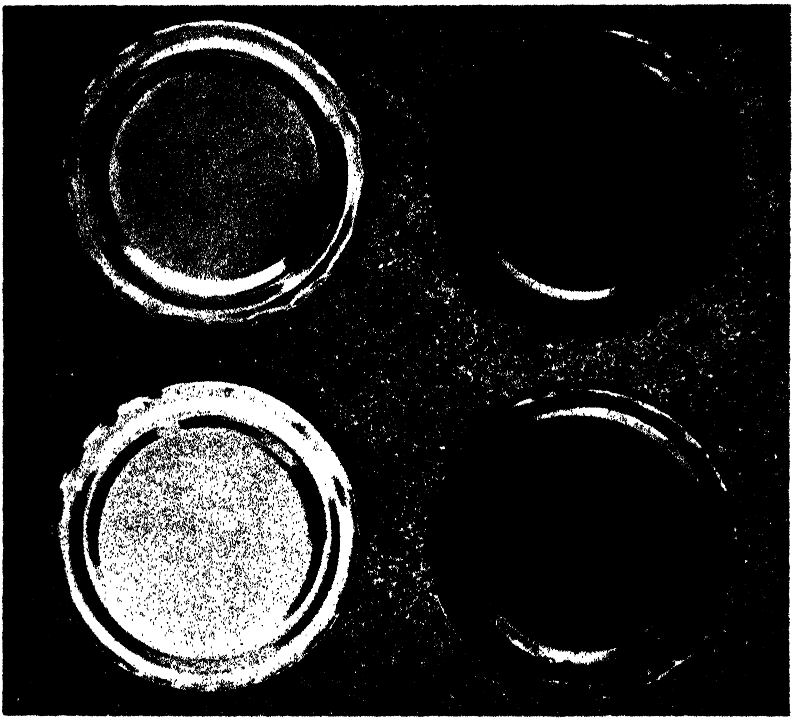

FIG. 1. Typical bottom end can covers removed seven months after packing. Non-acidulated, starch-free apple pectin of 50 grade was added at the approximate rate of 5 ounces per 100 gallons juice to the cans containing juice from which the left covers were removed. The covers on right are from control packs.

If enzymic clarified and filtered apple juice is to go into consumption within 30 days after packing, there would appear to be no object in adding pectin to prevent sedimentation. Furthermore, it is questionable if it is advisable to add pectin to juice that is packed in tin or brown bottles because the sediment usually adheres to the bottom of the container when the latter is emptied unless the container is shaken. Since the sediment detracts from the appearance of juice packed in clear glass bottles, it is recommended that the addition of 5 to 10 ounces of non-acidulated, starch-free, liquid, apple pectin of 50 grade will reduce the sedimentation to negligible amounts. This liquid pectin

should be thoroughly mixed with the apple juice before the latter is flash pasteurized for filling the containers.

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Handling Injuries on Pears Following Cold Storage

By Edwin Smith, *U. S. Department of Agriculture, Wenatchee, Wash.*

The usual practice in the Pacific Coast fruit districts has been to wash and pack pears immediately after harvest, before the fruit has been subjected to refrigeration. There is a widespread belief among pear shippers that the handling of pears while cold results in skin blemishes variously referred to as "finger prints," "belt burn," and "scald" which are frequently cited as causes of costly losses.

Results of the investigations covered by this report show that refrigeration did not make fruits of the Bartlett and Anjou varieties more susceptible to surface abrasions, but that resistance of the skin to injuries declined with advancing age in storage.

Materials and Methods

In 1941–1942, Anjou pears from orchards were washed and packed while warm, immediately after picking at Wenatchee, Washington and were compared with fruit held at 31, 36, and 40 degrees F for 10 and 21 days before washing and packing. No consistent differences were found in surface injuries. Since the degree of friction and pressure was not controlled in the commercial sorting and packing processes, experiments were conducted subsequently in which separate lots of 10 fruits were used for washing and for the application of uniform friction and pressure. These were replicated on fruit from three orchards in each experiment.

Uniform belt friction was applied with an instrument made by attaching a 12-inch piece of used canvas grading belt to a wood backing and affixing a handle. Using a guide to bring the same surface of the belt to each specimen, the instrument was drawn over a given spot on the cheek of a fruit with no pressure excepting its 6½ pound weight. Similarly, uniform brush friction was secured with a mounted 6½-inch used scrubbing brush, applying the action of the bristles at four points on each fruit. Uniform pressure friction was used to simulate the effects of the box lidding press of the packing-house. It consisted in placing a piece of paraffin-coated paper "chip-board" box-liner on the platform of a set of scales, pressing the cheek of a fruit against it until 75 pounds pressure was indicated and then twisting the fruit one quarter turn while under pressure.

In 1942, Anjou pears were picked at two stages of maturity from each orchard. The first picking was made a few days before commercial harvesting started and the second when the fruit had reached a desirable stage of maturity for harvesting (3). Samples were run through two types of commercial flood-type washers, one providing a single hydrochloric acid wash and the other a double wash of heated (98 to 100 degrees F) sodium silicate solution followed by slightly warmed (63 to 80 degrees) hydrochloric acid solution. Other samples were subjected to uniform belt friction, uniform pressure friction, and uniform brush friction. These treatments were applied immediately

after harvest with fruit at 70 degrees, and after storage at 31 degrees for 10 to 14 days before and after warming from 31 to 32 degrees to 36 to 38 degrees. After treatment the fruit was wrapped and stored at 31 degrees until examined in February.

In 1943 Bartlett pears were harvested at a desirable stage of maturity for fresh shipment (2). Samples were washed in a commercial double-process machine using heated (88 to 94 degrees F) solutions of sodium silicate and hydrochloric acid. Other samples were subjected to uniform friction and pressure treatments. The times of treatment were immediately after picking with fruit at 76 degrees, after 2 and 11 days' storage at 31 degrees with fruit temperatures at 32 degrees, and subsequent to warming to 40 degrees. Uniform friction and pressure treatments were also applied after fruit had been stored at 31 degrees for 32 days with fruit temperatures at 32 degrees, and at 40 degrees subsequent to warming. Anjou pears were picked at desirable stages of maturity (3) and samples from each orchard lot were subjected to uniform friction and pressure treatments while warm immediately after picking, and after storage at 31 degrees for 23, 51, and 79 days. One lot from each orchard was transferred from 31 to 36 degrees 1 month prior to the December 2 (79 days' storage) treatment. Bartlett pears were examined while being ripened subsequent to a month's storage. The Anjou variety was subjected to simulated transit conditions (45 degrees for 10 days) in December, then ripened for examination.

Experimental Results

The results from the treatments in 1942 are summarized in Table I. The experiments of 1943 were made to study the effects of handling the Bartlett variety while cold and to extend the storage period of the Anjou pears subjected to uniform friction and pressure treatments.

Effect of Washing Cold Fruit

Washing Anjou pears in heated solutions did not consistently result in more or less surface injury whether done when the fruit was warm immediately after harvest, cold (about 31 degrees F) after 2 weeks cold storage or warmed to 36 to 40 degrees after cold storage (Table I). Similar results were secured with the Bartlett variety in 1943. There was a greater variation in the appearance of the Bartlett variety between fruit from different orchards than from fruit from a single orchard washed at harvest with a temperature of 76 degrees and after cold storage either before or after warming to 40 degrees.

During each season a panel of three observers was unanimous in concluding that the temperature of the pears when washed did not alter their general appearance following subsequent storage and ripening.

Abrasions from Uniform Friction

The belt friction generally resulted in small areas of darkened epidermal tissue. With Bartletts in 1943, these abrasions were not sufficiently pronounced to make comparisons. With Anjous, the inten-

TABLE I—EFFECT OF HANDLING ANJOU PEARS AT DIFFERENT TEMPERATURES. EXAMINED BEFORE RIPENING, FEBRUARY 24–27, 1943.

Maturity	Fruit Temperature* (Degrees F)	Single Acid Wash (Abrasions)	Heated Double Wash (Abrasions)	Belt Friction (Abrasions)	Pressure Friction (Surface Injury)	Brush Friction (Abrasions)
			Orchard A			
Early.....	70	Moderate	Slight to moderate	None to moderate	None	Slight to moderate
Late......	70	None	None	Slight	None	Slight to moderate
Early.....	31	Moderate	Heavy	Slight	None	Slight to moderate
Late......	31	Slight	Moderate	Slight	None	Slight to severe
Early.....	36–38	Moderate	Heavy	Slight	None	Slight to moderate
Late......	36–38	None	None	Slight	None	Slight to severe
			Orchard B			
Early.....	70	Moderate	Moderate	None to slight	None	None to slight
Late......	70	Moderate	Moderate to severe	Slight to severe	None	Moderate
Early.....	31	Moderate	Moderate	None to slight	None	None to slight
Late......	31	None	None	Slight	None	Slight
Early.....	36–38	Moderate	Moderate	None to slight	None	None to slight
Late......	36–38	None	None	Trace	None	Slight
			Orchard C			
Early.....	70	Moderate	Moderate	Slight	———	Slight
Late......	70	None	None	Slight	None	None to severe
Early.....	31	Moderate	Moderate	None to slight	———	Slight
Late......	31	None	None	Trace	None	None to moderate
Early.....	36–38	Moderate	Moderate	None to slight	———	Slight
Late......	36–38	None	None	Trace	None	None to moderate

*Fruit was handled at 70° at harvest; at 31° and, after being warmed, at 36° to 38°, following 10 to 14 days' storage in a 31° room.

sity of markings was about the same regardless of fruit temperature at the time of application (Table I).

Abrasions from the stiff bristles of a dry brush made slight scratches on the skin of many fruits. Brush marks were not noticeably different on fruit brushed while warm immediately after picking or while cold after storage at 31 degrees up to 14 days.

While the data in Table I indicate no consistently adverse effects of handling Anjou pears while cold, they show that abrasions from washing and belt friction were least severe on fruit harvested at an optimum stage of maturity and that scratches from the brush were generally least pronounced on the pears harvested while slightly immature. This may indicate that the development of cutin protected the fruits against certain types of friction but did not give protection against the stiff bristles of a dry brush.

BRUISE MARKS FROM UNIFORM PRESSURE FRICTION

Pressing Bartlett and Anjou pears against a flat surface under 75 pounds pressure generally resulted in flattened areas about ¾ inch in

diameter. When the fruit was subsequently stored it was not under pressure and these flattened areas disappeared before examination excepting when the interval between bruising and examination was only a few days. In no instance was a discolored bruise formed that could be correlated with the temperature of the fruit when placed under pressure.

When fruits were cut through the bruised tissue, many of those subjected to pressure while at a temperature of 31 degrees F had a chalk-colored zone of tissue cleavage from ⅛ to $^3/_{16}$ inch beneath the skin. This was less frequent in fruits warmed to 38 to 40 degrees before applying pressure and was rarely seen or very inconspicious when fruits were handled at harvest before refrigeration. This injury did not alter the outward appearance of the fruit, could not be detected in paring the skin, and would not result in wastage in the hands of the consumer.

Relation of Prolonged Storage to Fruit Injuries

Storing Bartlett pears four weeks at 31 degrees F before applying the uniform belt, brush, or pressure friction did not make any noticeable difference in surface injuries. Since a slower rate of cooling or higher fruit temperature during the storage would result in an accelerated ripening rate (2), the same results might not always follow when commercial cold storage is used.

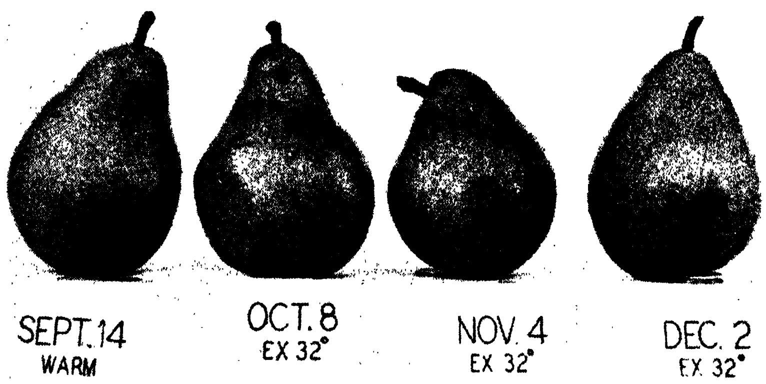

Fig. 1. Anjou pears subjected to uniform belt friction at time of harvest and after 31 degrees F storage while fruit was cold (32 degrees F). 1943.

As illustrated in Fig. I, abrasions from uniform belt friction applied to Anjou pears at time of harvest, September 14, 1943, and while at 32 degrees F after 23 days' storage were very inconspicuous; when applied November 4, abrasions were more conspicuous; and, when applied December 2, abrasion injuries caused marked disfigurement. The lots held at 36 degrees after November 4 and subjected to belt friction December 2 had the greatest degree of "belt burn."

Warming the fruit from 31 degrees to 38 to 40 degrees F before

brushing did not result in less injury. After 7 weeks (November 4) pronounced scratches resulted on most fruits and after 11 weeks (December 2) deep scratches were produced and these became unsightly with ripening. The skin was torn away by the brush on some specimens held at 36 degrees from November 4.

Abrasions or bruises from twisting Anjou fruits against the "chip board" box liners while under 75 pounds pressure rarely were evident excepting on fruits handled on December 2. Slightly darkened areas appeared where the latter fruits received the pressure friction and some of these turned brown as the fruit ripened.

Conclusions

These studies show that the abrasion marks commonly manifested following the commercial packing of Bartlett and Anjou pears subsequent to cold storage do not result from any physiological influence of refrigeration or from handling the fruit while cold. Instead the disfigurement seems to be related to the age or stage of ripeness of the fruit when handled.

The results can be applied to commercial practice because it is known that old age or senility in pears is hastened when fruit is not cooled rapidly to, and held at, optimum storage temperatures of 29 to 31 degrees F (1, 2, 4, and 5). A minimum of abrasion injuries will follow if the pears are washed and packed as soon as harvested.

However, where it is possible to place pears under refrigeration on the day of harvest, thoroughly cool them to 31 degrees F within a short time, and keep them at that temperature, it is possible to postpone the washing and packing of Bartletts and Anjous for a considerable time without serious risk of increased surface markings. Thus, with prompt and adequate refrigeration the packing season for Bartletts may be safely extended 2 to 3 weeks and that of Anjous for 6 to 7 weeks after the fruit has been picked. Fruit so handled may be washed and packed without previous warming.

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Effect of Some Growth-Regulating Substances on the Rate of Softening, Respiration, and Soluble Solids Content of Peaches and Apples

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The influence of ethylene in stimulating the rate of respiration and softening of many species of preclimacteric fruit has been demonstrated by Gane (2), Kidd and West (5), and Smock (8). Recently the work of Gerhardt and Allmendinger (3) with preharvest a-naphthaleneacetic acid sprays on pears and apples and Mitchell and Marth (6) with 2,4–dichlorophenoxyacetic acid on apples, pears, and bananas indicates that other organic substances, also, are capable of hastening the ripening of preclimacteric fruit.

Although ethylene stimulates the rate of ripening of some fruits, it inhibits the sprouting of potatoes and peas (1, 7). A similar inhibiting action on potatoes has been demonstrated by Guthrie (4) with the methyl ester of a-naphthaleneacetic acid. Consequently, in some preliminary work on the influence of various growth-regulating substances on fruit, this compound, in particular, was tested to determine its influence on the rate of softening, soluble-solids content, and respiration of peaches and apples to determine whether it hastens fruit ripening.

Methods and Materials

Respiration measurements were made from composited lots of fruit containing from 18 to 20 blemish-free specimens each. The peaches were harvested from the Cornell University Orchard at Ithaca, New York; the McIntosh apples were collected in Burnt Hills, New York. The time of picking and the conditions under which the fruit held following harvest are indicated in Figs. 1 and 2. Each lot of fruit was placed in a half-bushel container and submerged in a constant water bath at 74 degrees F during the period that the measurements were made. The rate of respiration was determined by measuring the milligrams of carbon dioxide produced per kilogram of fruit per hour, as previously discussed (9).

Measurements of the firmness of the flesh were made by using a Magness-Taylor pressure tester with a $^5/_{16}$-inch plunger. The percentage of soluble solids in the juice was read directly from a portable Zeiss refractometer. The U. S. D. A. ground-color chart for western apples and pears was employed to distinguish changes in ground-color development after treatments with growth-regulating substances.

The chemicals tested include 2,4–dichlorophenoxyacetic acid, methyl and ethyl esters of a-naphthaleneacetic acid, and two Dow Chemical Company preparations called "Stor-Aid No. 1" and "Stor-Aid No. 2". In all instances where solutions of 2,4–dichlorophenoxyacetic acid were used a 0.5 per cent solution of Carbowax 1500 was added. Weighed amounts of the chemically pure (95 to 100 per cent) liquid esters were absorbed on shredded filter paper which was distributed uniformly about the fruit. The Stor-Aid No. 1 contained 3

per cent of methyl a-naphthaleneacetate and 97 per cent of confetti by weight. Stor-Aid No. 2 contained 2 per cent of the same ester and 98 per cent of talc. These two preparations were developed for use on potatoes to inhibit sprouting. For this purpose it was suggested by the manufacturer that Stor-Aid No. 1 and 2 be used at the rate of 10 to 20 pounds per 100 bushels of potatoes, respectively.

Further details pertaining to the methods of application and concentrations of the materials employed are given as the experiments are discussed in the text.

Effect of Treatment on Detached Fruits

Rate of Softening:—On August 22, 1945, some preclimacteric Halehaven peaches were harvested at Ithaca and divided into lots of eight fruits each. After treatment each lot was placed in a closed paper bag at room temperature. The treatments and their influence on the rate of softening are indicated in Table I.

TABLE I—The Influence of Certain Organic Chemicals on the Rate of Softening of Harvested Halehaven Peaches

Treatment August 22, 1945	Pressure in Pounds August 25, 1945	General Average
1. 2,4-dichlorophenoxyacetic acid (500 ppm) +0.5 per cent Carbowax**	6, 7, 5, 5, 6, 7, 6, 6	6.0
2. 2,4-dichlorophenoxyacetic acid (1000 ppm) +0.5 per cent Carbowax**	4, 6, 5, 6, 5, 9, 6, 5	5.8
3. Stor-Aid No. 1 (1 gm per 600 gms of fruit)	4, 3, 4, 3, 3, 8, 5, 5	4.4
4. Stor-Aid No. 2 (2 gms per 600 gms of fruit)	4, 5, 3, 4, 4, 3, 4, 3	3.8
5. Methyl ester of a-naphthaleneacetic acid (400 mg per kg of fruit)	5, 5, 5, 6, 3, 8, 8, 5	5.6
6. Ethyl ester of a-naphthaleneacetic acid (400 mg per kg of fruit)	6, 6, 5, 7, 4, 5, 8, 7	6.0
7. 0.5 per cent Carbowax	30*, 15, 30*, 30*, 30*, 30*, 30*, 30*	31.3
8. Control	30*, 30*, 30*, 30*, 27, 28, 19, 14	28.5

Firmness of flesh exceeded 30 pounds at harvest (Aug 22, 1945), maximum for the tester used.
*Over 30 pounds.
**Fruit submerged in this solution 5 to 10 seconds.

It can be readily seen from the data that 2.4–dichlorophenoxyacetic acid and the preparations containing the esters of a-naphthaleneacetic acid markedly hastened the rate of softening of these peaches.

Similar treatments on immature Veteran and Elberta peaches at identical concentrations accelerated their rate of softening, also. Stor-Aid No. 2 applied to the fruit with a hand duster hastened ripening of immature peaches to as great an extent as did the larger, measured amounts used.

The influence of Stor-Aid No. 1 and 2 on the rate of softening, ground-color change, and percentage of soluble solids of some McIntosh, previously stored at 40 degrees F with 2 per cent oxygen and 5 per cent carbon dioxide, is shown in Table II.

From these data, it may be seen that treatments of 1 and 2 grams of Stor-Aid No. 1 and 2, respectively, per 600 grams of fruit accelerated the rate of softening and the development of a yellower ground color but did not influence the soluble-solids content. The absence of an effect on the percentage of soluble solids was similar to that obtained from such treatments on detached peaches, also. However, an

TABLE II—THE INFLUENCE OF STOR-AID NO. 1 AND 2 ON THE FIRMNESS, GROUND COLOR, AND PERCENTAGE OF SOLUBLE SOLIDS OF McINTOSH APPLES AT 74 DEGREES F*

Treatment	Date Treated	8 Days After Treatment††		
		Pressure (Pounds)	Soluble Solids (Per Cent)	Ground Color
Stor-Aid No. 1 (1 gm/600 gms of fruit)	Nov 14, 1945**	9.6	10.9	3.5–4
Stor-Aid No. 2 (dusted on fruit)	Nov 14, 1945**	10.3	10.9	3–3.5
Control	Nov 14, 1945**	10.2	10.8	3–3.5
Stor-Aid No. 1 (1 gm/600 gms of fruit)	Nov 28, 1945†	9.9	11.0	3–3.5
Stor-Aid No. 2 (2 gms/600 gms of fruit)	Nov 28, 1945†	10.0	10.9	3–3.5
Control	Nov 28, 1945†	10.6	10.9	2–3

*Apples were held at approximately 40 degrees F with 2 per cent oxygen and 5 per cent carbon dioxide from time of harvest until the time of treatment in November.
**On Nov. 14, 1945 the fruit had a firmness of 15.2 pounds, 11.1 per cent soluble solids, and a ground color of 2.
†On Nov. 28, 1945 the fruit had a firmness of 16.2 pounds, 11.0 per cent soluble solids, and a ground color of 2.
††Average from 18 to 20 apples.

application of Stor-Aid No. 2 with a hand-duster failed to hasten the rate of ripening of these McIntosh apples, in contrast to its ripening influence on peaches.

Rate of respiration:[1]—The data obtained from treatments of 2,4–dichlorophenoxyacetic acid and Stor-Aid No. 1 and 2 on the rate of respiration of immature Veteran peaches are given in Fig. 1. These materials markedly increased the rate of respiration. A solution containing 500 ppm of 2,4–dichlorophenoxyacetic acid, in which peaches were dipped for 5 to 10 seconds, stimulated the rate of respiration to a greater extent than did the quantities of Stor-Aid No. 1 and 2 that were used.

Fig. 2 is typical of data obtained from McIntosh treated with Stor-Aid No. 1 and 2. The rate of respiration was accelerated when 1 and 2 grams of the Stor-Aid No. 1 and 2, respectively, were used. Results obtained from another lot of these apples showed that dust applications of Stor-Aid No. 2 had no effect on the rate of carbon dioxide production, however. The failure of such dusting treatment to hasten the ripening of McIntosh apples, in contrast to its effect on peaches, may be due to the fact that more dust tends to cling to the fuzzy surface of a peach. It is conceivable, also, that peaches may respond to lower concentrations of this chemical.

Some preliminary work was done in Wayne County on bearing Halehaven, Veteran, and Elberta trees in an effort to determine the influence of applications of the methyl ester of a-naphthaleneacetic acid on rate of softening and on eating quality of undetached peaches. In these tests three similar trees of each variety were selected and one or two unit branches per tree were treated with Stor-Aid No. 2 applied from a hand-duster. Similar limbs on the same trees were selected as controls.

In all instances where this dust was applied, from 1 to 3 weeks be-

[1]The assistance of C. R. Gross and M. L. McMahon, Department of Pomology, Cornell University, in making the respiration measurements was greatly appreciated and is hereby acknowledged.

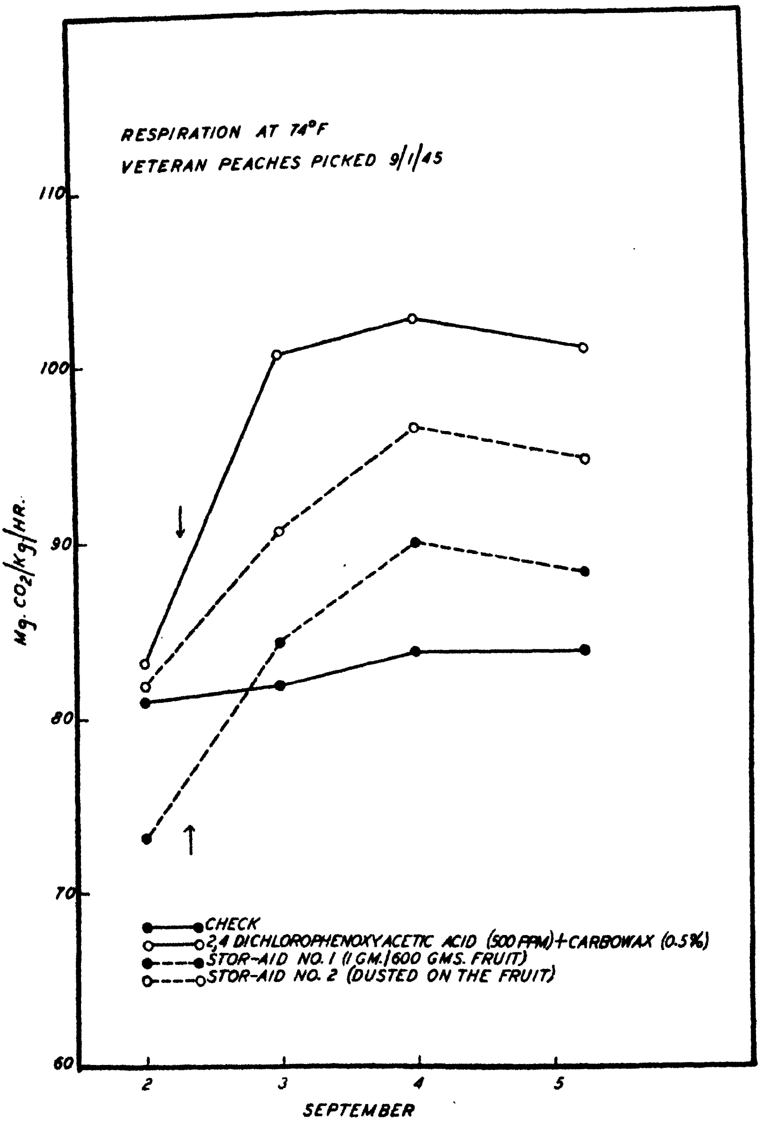

FIG. 1. The influence of 2,4-dichlorophenoxyacetic acid and materials containing the methyl ester of a-naphthaleneacetic acid on the rate of respiration of Veteran peaches.

fore harvest, the fruits were softer (up to 8 pounds) and yellower, 6 to 17 days following treatment, than fruits from untreated sections of the same trees. With the varieties Halehaven and Veteran this ripening influence was more pronounced than with Elberta. However, Stor-Aid No. 2 badly injured the foliage of the varieties Halehaven and Veteran. The injury to Elberta foliage was slight by comparison.

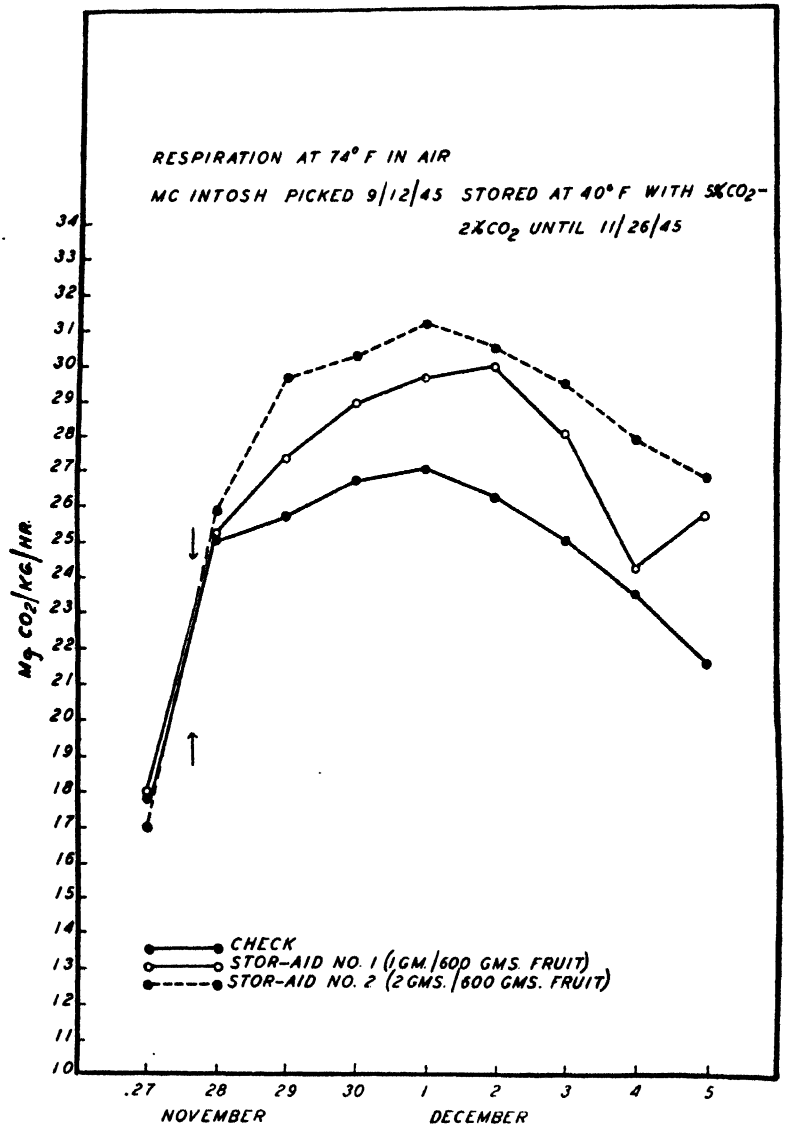

FIG. 2. The influence of some materials containing the methyl ester of a-naphthaleneacetic acid on the rate of respiration of McIntosh apples.

Consequently, it is possible that the influence of this dust on ripening was due, in part at least, to its harmful effect on the foliage.

The eating quality of the peaches harvested from branches treated with Stor-Aid No. 2 was distinctly poorer wherever the foliage suffered injury. In general, the greater the foliage injury the lower was the soluble solids content of the fruit in comparison with fruit from

similar untreated limbs. For instance, Halehaven limbs dusted on August 29 yielded fruits averaging 8.7 per cent soluble solids on September 10. The foliage on these limbs was severely scorched. Similar fruits from control limbs averaged 10.0 per cent of solids. However, fruits from Elberta limbs similarly treated and showing no appreciable leaf injury 17 days later contained 9.0 per cent soluble solids, as compared with 9.2 per cent in fruits from untreated limbs. Eating quality was not noticeably affected in this latter instance.

Discussion

A means of hastening the rate of softening of harvested peaches might be of value to canners. Even carefully harvested peaches vary considerably in firmness. A method of rapidly softening the less mature fruits in a given lot might result in a reduction in the amount of handling and sorting necessary before processing. From the results presented it appears that both 2,4-dichlorophenoxyacetic acid and the preparations containing the methyl and ethyl esters of a-naphthalene-acetic acid will markedly hasten the rate of softening of immature detached peaches.

Peach growers might find the use of a material capable of hastening maturity of some value when trees are high in nitrogen and a plentiful supply of water is available or in areas where cool weather is likely to persist at harvest time. It is under such conditions that fruit ripening is delayed. Also, the rate of maturation of individual fruits on a given tree is likely to vary considerably and to necessitate several pickings to avoid harvesting some extremely immature peaches. Applications of a talc dust containing 3 per cent of methyl a-naphthaleneacetate to bearing peach trees hastened ripening but resulted in severe foliage injury and lowered fruit quality. This harmful influence to the leaves and fruit quality might be largely eliminated by the use of lower concentrations of this material. Further work is necessary, also, to determine its influence on fruit drop and brown rot.

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The Effect of Potato Leaf Hopper on the Size, Color, and Condition of Plum Foliage

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FOR several years it has been observed in Michigan that the foliage on plum trees has been small, distorted in shape, and brownish green in color. Yields of fruit have often been so low that the growing of plums has not been profitable. During the summer of 1944, a survey was made in southwestern Michigan to determine the cause of this condition.

Mineral deficiencies were suggested as a possible cause of the trouble. To determine if this was the case, an orchard was selected where the trees exhibited these symptoms, growing on a Newton soil profile. Fertilizer trials were made with phosphorus, potash, and boron, applied in the fall of 1944, and with nitrogen applied in the spring of 1945.

The possibility that potato leaf hoppers were responsible for this foliage condition was also considered. As a consequence, cheese cloth bags were made to cover two medium sized branches on each of the trees in the plots. The bags were soaked in DDT, a water suspension of 25 per cent wettable powder, and dried before placing over the branches on June 6, 1945, where they remained throughout the balance of the growing season. The purpose of the bags and treating them with DDT was to protect the leaves from insect injury.

The branches were examined from time to time and the condition of the foliage observed. The leaves on the covered branches were large,

FIG. 1. Twigs at the left taken from portion of branch covered with a bag; twigs at the right from the exposed portion of the branch.

broad and glossy green, irrespective of the fertilizer treatment, while the condition of the foliage on the exposed branches was the same as in previous seasons. Fig. 1 shows four twigs from the same branch from one of the trees receiving complete fertilizer. The leaves on the two twigs at the left, taken from a portion of the branch covered with a bag, were large, dark glossy green and typical of vigorous, healthy foliage. The leaves from the two twigs at the right, from the exposed portion of the branch, were small, distorted, brownish green and brittle. This condition was typical throughout the orchard.

Near the close of the growing season the bags were removed from the branches and random samples of leaves were collected. One sample was from foliage protected by the bags, the other from foliage exposed to potato leaf hopper attacks. Two hundred leaves were collected for each sample. These leaves were pressed and later measured. A summary of these measurements is given in Table I. The data indicate clearly that in this orchard, dwarfing and contortion of leaves was caused by exposure to insect attack. Observations would lead to the belief that the principal causal agent was the potato leaf hopper. Furthermore, it is evident that the foliage injury was extreme enough to account for the rather poor performance of the trees.

TABLE I—SUMMARY OF LEAF MEASUREMENTS FROM STANLEY PRUNES GROWING ON NEWTON SOIL

Description	Open	Covered
Total length in inches*	270.86	546.74
Total width in inches	173.63	344.16
Average length per leaf (inches)	1.32	2.64
Average width per leaf (inches)	0.84	1.66
Total area in square inches	173.89	616.25
Average area in square inches per leaf	0.85	2.98

*Measurements taken from 200 leaves in both cases.

Estimation of the Later Period of Almond and Apricot Fruit Growth from Earlier Measurements

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IF very extensive data over many years for a particular locality and variety are not available, the best basis for estimating the latter part of growth and the final average size is the growth already made during the current season. With adequate mathematical methods, a growth curve can be fitted to an earlier part of the growth of the fruit and then extrapolated for an estimate of the latter part of growth and final average size.

Baker (1, 2, 3 and 4) has developed mathematical methods that are sufficient, from the standpoint of description, for dealing with growth of a variety of biological forms. Under these methods, part of the growth curve can be used to determine a mathematical formula which can be extrapolated for some distance without danger of serious error. Baker and Davis (4) have used this approach to obtain a more realistic treatment of the growth of cheek diameter in peaches than that given by Miki (7). The present study is based on Royal apricot and Nonpareil almond fruits grown at Davis; the entire growth of the latter fruit corresponds to the first and second stages of development of such fleshy drupaceous fruits as peaches and apricots (5). The same methods are applicable to the growth of linear dimensions of peaches and probably applicable to other stone fruits if data are available for the proper portions of the growth.

The purposes of this paper are: (a) to represent mathematically the growth of Nonpareil almonds and Royal apricots; and (b) to see how small a portion of these curves can be used as bases for representing the growth from some initial time to final size.

The data consist of periodic measurements on cheek diameter for 138 tagged Nonpareil almonds and 174 tagged Royal apricots, each scattered among the lower branches of a mature tree. The almonds were measured every 7 days, beginning March 21, 17 days after full bloom; thus measurements were started in Stage I (5). Apricot measurements were started in Stage II when the pits were light brown on the outside and buff on the inside (May 28) and were measured every 3 days. Table I gives the average cheek diameters, with dates of measurements for both apricots and almonds. On June 27 the most advanced apricot fruits were becoming too soft to measure; these fruits were carried at their largest size in the computing of subsequent averages. Growth was completed by all fruits by July 9.

For our purpose it is sufficient to assume that the curve of 7-day and 3-day increments in growth can be represented by the mathematical formula

$$\text{(A)} \qquad \frac{y_{t+1}}{y_t} = 1 + \frac{a - t}{b_0 + b_1 t + b_2 t^2}.$$

The variable t represents time and takes integral values, the unit of

measurement being 7 days or 3 days; y_t the increment corresponding to time t; and y_{t+1} the increment corresponding to time $t+1$ or one period later. The constant a locates the time of most rapid growth. The constants b_0, b_1, and b_2 determine the spread and skewness of the distribution of the increments about the time of most rapid growth a. One or more of the b's may be zero. Since there are three or four constants to be determined, one must have a few more than three or four observed increments, to allow smoothing out of transient environmental effects. Further details of fitting formula A to "stumps" or parts of observed distributions are technical and are adequately described by Carver (6).

Formula A was applied to the data of Table I. The first five weekly

TABLE I—AVERAGE CHEEK DIAMETERS IN MILLIMETERS FOR THE SAME 138 NONPAREIL ALMOND FRUITS AT WEEKLY INTERVALS (1944) AND FOR THE SAME 174 ROYAL APRICOT FRUITS AT THREE-DAY INTERVALS (1945), DAVIS, CALIFORNIA

Nonpareil Almonds		Royal Apricots	
Date	Average (Mm)	Date	Average (Mm)
Mar 21	7.00	May 28	29.05
Mar 28	9.65	May 31	29.38
Apr 4	13.80	June 3	29.78
Apr 11	16.95	June 6	30.53
Apr 18	19.08	June 9	31.53
Apr 25	20.22	June 12	32.68
May 2	20.89	June 15	34.10
May 9	21.34	June 18	35.67
May 16	21.32	June 21	37.06
May 23	21.28	June 24	38.48
——	——	June 27	39.84
——	——	June 30	40.75
——	——	July 3	41.43
——	——	July 6	41.85
——	——	July 9	41.94
——	——	July 12	41.94

increments or the first six average measurements for almonds had to be used in order to get a satisfactory representation of growth to the end of the growing period. The mathematical representation using almond data thus obtained with b_2 assumed equal to zero is

$$\text{(B)} \qquad \frac{y_{t+1}}{y_t} = \frac{1.0745 + 0.4911\,t}{-0.4472 + 1.4911\,t}.$$

Similarly the first 11 averages for apricots were used in determining the mathematical representation of the 3-day increments. In order to represent adequately the last stage of growth it is necessary to assume $b_2 \pm 0$. If this is done we get

$$\text{(C)} \qquad \frac{y_{t+1}}{y_t} = \frac{404.1876 - 15.0192\,t - t^2}{266.3957 + 7.0959\,t - t^2}.$$

Table II shows the correspondence between observed and calculated 7-day and 3-day increments, and between observed and computed final sizes for apricots and almonds. The calculated values in Table II agree very well with the observed values, even though only

part of the observed data was used in computing the constants given in formulas B and C. In the case of apricots 15.7 per cent of the growth from May 28 to final size was extrapolated satisfactorily (with an error of less than 5 per cent). In the case of the almonds 7.4 per cent of the growth from March 21 to final size was extrapolated with an error of less than 1 per cent.

TABLE II—COMPARISON OF COMPUTED AND OBSERVED PERIODIC INCREMENTS AND FINAL SIZE IN MILLIMETERS FOR NONPAREIL ALMOND FRUITS (1944) AND ROYAL APRICOTS (1945) DAVIS, CALIFORNIA

Nonpareil Almonds			Royal Apricots		
t 1 Unit = 1 Week	Observed (Mm)	Computed (Mm)	t 1 Unit = 3 Days	Observed (Mm)	Computed (Mm)
1	2.65	2.69	0	0.330	0.324
2	4.15	4.04	1	0.406	0.492
3	3.15	3.28	2	0.745	0.701
4	2.13	2.07	3	0.999	0.939
5	1.14	1.14	4	1.152	1.179
—	—	—	5	1.418	1.388
6**	0.67	0.58	6	1.571	1.524
7	0.45	0.27	7	1.392	1.553
8	-0.02*	0.12	8	1.419	1.454
9	-0.04*	0.05	9	1.357	1.234
10	—	0.02	—	—	—
11	—	0.01	10**	0.917	0.931
—	—	—	11	0.680	0.604
—	—	—	12	0.420	0.319
—	—	—	13	0.084	0.123
—	—	—	14	0.000	0.026
Total increment	14.28	14.27	—	12.890	12.791
Beginning size	—	7.00	—	—	29.05
Final size	21.28	21.27	—	41.940	41.84

*Negative increments are due to unavoidable errors in measurements or, possibly to shrinkage. The standard deviation of an individual measurement was about 0.23 millimeters.

**Computed increments for these and later values of t are given by formulas B and C and do not depend upon the observed increments for the later values of t.

In attempting to predict the final size of the fruit that remains on the tree until full growth is attained, one must start with more tagged fruit than will be desired in the final analysis, because some fruit tagged early in the season will drop prematurely. The method lends itself to a continuous succession of estimates as the season progresses. One should remember, however, that the periods of relatively most rapid growth (Stage I for almonds and Stages I and III for apricots) are critical values of time since in order to secure a good estimate of subsequent growth it is necessary to get a measure of the rate of decrease from the maximum value of the periodic increments of growth. Thus to secure a good estimate of growth from some initial time on one must go somewhat beyond this critical time. With apricots, for instance, whose growth consists of the combination of at least two formulas of type A, the present method has been applied to the latter part of growth. We found it necessary to extend the observations beyond the last period of relatively most rapid growth in order to estimate the final size. A similar procedure might be applied to the earlier period of growth to furnish an estimate of the size at the end of this phase; the size at the end of the first phase is closely related to the type of thinning that needs to be done.

Summary

A method of representing the latter part of growth based on data collected in the current season, is applied to estimating the final size of Nonpareil almonds and Royal apricots. It is found that six average size determinations at weekly intervals were sufficient with a three-constant formula to determine the growth curve from the beginning of the period, March 21, to the end of growth for Nonpareil almonds.

Eleven averages at 3-day intervals beginning when the pits were light brown on the outside and buff on the inside are sufficient, with a 4-constant formula, for determining the growth curve of average cheek diameter of Royal apricots from May 28 to the end of the season. Apparently any method of representing the growth of fruits from some initial time on in terms of the earlier part of the measurements and, hence, estimating final average size based only on the growth of a particular variety of fruit in a particular locality during the current season must proceed along the lines indicated.

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Foliar Diagnosis: An Approach to the Control of the Nutrition of Apple Trees

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Introduction

The apple trees constituting this study were of the York variety grown in the College experimental orchard No. 1. Planted in 1907, the trees in rows 2, 3, and 4 were below average size; whereas those of rows 31 and 32 were of average size. The differences in vigor were the result of divergent cultivation systems: rows 2, 3, and 4 were tilled throughout the growing season, and received no fertilizer from 1908 to 1919; in 1920, these rows were seeded to mixed grass and legume sod which was maintained continuously until 1928, after which the sod was broken every few years; between 1921 and 1934, row 2 received 10 pounds of nitrate of soda, and row 3, 5 pounds, while row 4 was unfertilized; from 1934 to 1943, all three rows received the amounts of nitrate of soda just mentioned, together with 5 pounds of 20 per cent superphosphate and 1 pound of either muriate or sulphate of potash, and in 1944, these treatments were modified as shown in Table I.

Rows 31 and 32 were tilled during the early summer and seeded to a cover crop about midsummer, and were fertilized with a complete commercial fertilizer with an analysis of approximately 4–8–6, from 1908 to 1928; from 1928 to 1934, these rows were maintained in blue grass sod, which was broken every few years, and to which 10 pounds each of nitrate of soda and 16 per cent superphosphate were added to the tree. From 1934 until 1944, row 31 received five pounds each of nitrate of soda and superphosphate and 1 pound of muriate of potash to the tree, while row 32 has received 10 pounds of nitrate of soda to the tree and the same amounts of superphosphate and muriate of potash as were applied to row 31, and the sod maintained in both rows has been mixed blue grass and legumes (1, 2).

On the basis of the analytical results of leaf samples taken in 1943, the changes designated later were made the following spring in the regular annual applications to each tree. The purpose was to ascertain to what extent the method may be used as a tool in controlling nutrition. The experiments are necessarily preliminary, and the difficulties obvious. The relation of mineral nutrition of fruit trees to yields is of a complex nature, since yields are a resultant of fruit bud formation, fruit setting, and subsequent development. New tissue growth in early spring is at the expense of stored nutrients, adding further to the complexity of the problem of the relation of fertilizer applied to leaf mineral content in a particular season. Cross feeding undoubtedly is an additional disturbing factor. In the case of phosphorus and potassium it is known that, relatively, much larger amounts of these

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elements are required for fruit production than for vegetative growth alone, and that much more enters the fruit than falls with the leaves. The magnitude of this influence in relation to studies on foliar diagnosis requires investigation.

Experiment

Sampling:—The leaf samples were taken from the middle portion of the current season's non-bearing shoot growth on June 18, July 7, July 28, and August 18 in 1943; and on June 16, July 5, July 27, and August 14 in 1944, at approximately the same physiological stages in both years. Twenty to 25 leaves were taken at each sampling around each tree.

Presentation of data:—The regular fertilizer treatments up to 1943, the changes in treatments given in 1944, the yields in both years together with the total yields up to 1944 are given in Table I.

Fig. 1 presents the change in the nitrogen, phosphoric acid, and potash content respectively of the leaves from each tree in the two seasons compared. The values in each case are obtained by taking the

TABLE I—Fertilizer Treatments and Yields of Apples in 1943 and 1944

Tree No.	Fertilizer Treatments: To 1943 Pounds (Annually)	Fertilizer Treatments: Change Made in 1944	Yield (Bushels) 1943	Yield (Bushels) 1944	Total Yield 1907–1944	Per Cent Increase or Decrease in Yield of 1944 Relative to 1943
C2	10 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual applications plus 5 lb. K_2SO_4	6.0	14.0	115.09	+133.3
D2	10 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual applications plus 5 lb. K_2SO_4	12.4	13.5	164.67	+ 0.9
C3	5 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual application plus 5 lb. K_2SO_4	5.9	22.5	209.77	+281.3
D3	5 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual application plus 5 lb. K_2SO_4	11.5	17.0	183.07	+ 47.8
C4	5 Superphosphate, 1 K_2SO_4	Regular application of K_2SO_4. Superphosphate omitted, plus 10 lb. $NaNO_3$	7.0	0.0	41.30	−100.00
D4	5 Superphosphate, 1 K_2SO_4	Regular annual application plus 5 lb. K_2SO_4	17.2	0.4	137.72	− 97.6
C31	5 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual application plus 10 lb. $NaNO_3$, plus 10 lb. Superphosphate	23.0	14.0	261.05	− 39.6
D31	5 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual application. No change made	23.6	8.0	266.85	− 66.1
C32	10 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual application plus 10 lb. $NaNO_3$ +10 lb. Superphosphate	18.4	29.0	296.51	+ 57.6
D32	10 $NaNO_3$, 5 Superphosphate, 1 K_2SO_4	Regular annual application plus 15 lbs. K_2SO_4	22.0	17.5	314.58	−20.4

mean of the values for N, P_2O_5 and K_2O respectively at each of the four sampling dates in each year. They represent in each case, consequently, the resultant of all the factors influencing the content of each element in the leaf during the respective growth seasons. All results are expressed in terms of percentages in the dried foliage. The results could also be presented by a figure showing the changes in detail from one sampling to another, as described in the succeeding paper. The method used in this paper is, however, best suited to the purpose at hand.

The horizontal lines of Fig. 1 indicate the tentative optimum values for nitrogen, potash, and phosphoric acid reading downwards as indicated in the legend to Fig. 1 for one of the most vigorous trees (C32) in 1944, the year of higher production of fruit for this tree; the yield of which was, moreover, the highest of the trees considered in this paper for the years under comparison.

These optima, therefore, indicate the level at which the supply to the leaves in relation to the demand thereon is optimum for the respective elements. The position of each of these lines of optimum values represents, within a relatively narrow area for each, namely, within that of the analytical error, the tentative optimum for the leaf content of that element. The analytical error is less than two per cent of the values indicated.

The black circles represent the values obtained for the year 1943 and the head of the arrow those for the year 1944. The displacement, that is, the change in the index values for each element for the two years under comparison is represented by a line joining the locus for 1943 with that for 1944. The yields of fruit in bushels obtained from each tree in each of the years, and also the differences in yield in bushels obtained in 1944 from those of the respective trees in 1943 are indicated by the columns on the base line, an increase being represented above and a decrease below the abscissa as indicated in the legend of Fig. 1.

Fig. 2 represents the results in a different manner, namely, as displacements of the *NPK-units*.

Weather conditions:—The contrast in weather conditions during the two seasons was not very marked. There was little difference in mean temperature (.4 degree higher in 1943). The total rainfall in the 1943 season was greater than in 1944 by 1.62 inches and was distributed differently; the period from June 18 to July 4 was relatively dry in 1943 (.35 inch of rainfall compared with 1.27 inches during the same period in 1944). The percentage of sunshine was 13 per cent greater during the 1944 growing season than during that of 1943.

Discussion and Interpretation of Results

Nutrition in the two seasons considered separately:—It should be kept in mind in reading Fig. 1 that any particular locus indicates the relation of supply of that element to the demand on it and is presented as a net or resultant for the growing season.

Considering the levels of the respective elements in 1943, it is seen that in the case of nitrogen the leaf contents of this element bear no

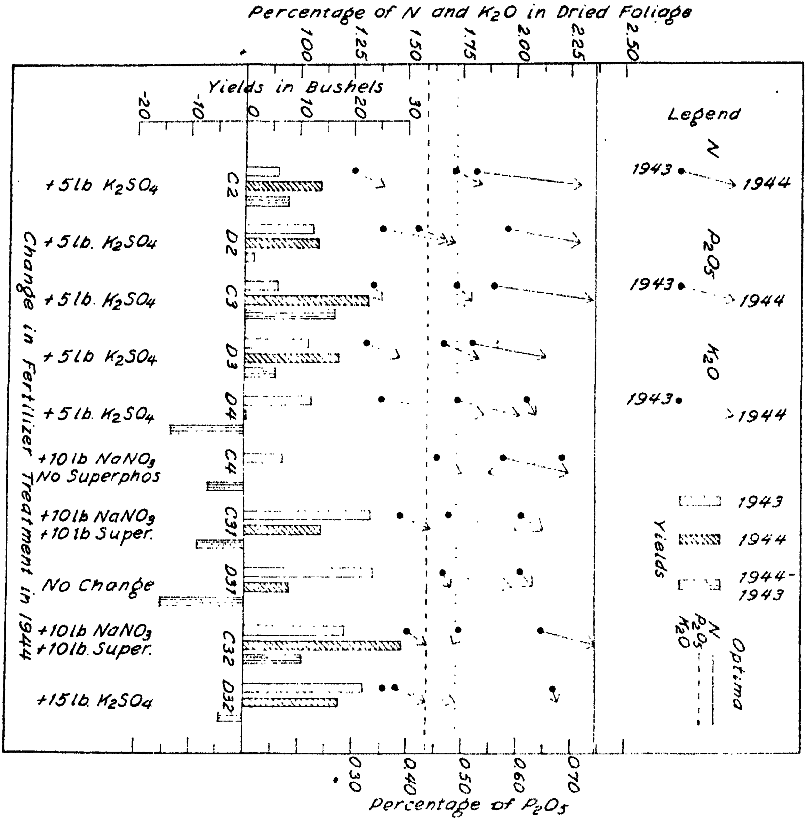

FIG. 1. Displacements of the percentage contents of N, P_2O_5, and K_2O in dried foliage of apple trees in 1943 and 1944, in relation to optimum values, to yields of fruit, and to changes in fertilizer applications in the spring of 1944.

relation to the fertilizer treatments. Thus the content of nitrogen in 1943 in tree C2 which received 10 pounds of $NaNO_3$ annually is lower by 12 per cent of the value of tree D4 which has never received any nitrogen dressings, and is at about the same level as that of tree D3 which received 5 pounds $NaNO_3$ annually. Again the nitrogen content of tree C31 which received 5 pounds $NaNO_3$ annually differs by only 1.3 per cent of the value of tree C32 which received 10 pounds of $NaNO_3$ annually; this is within the limits of analytical error. The content of potash in relation to fertilizer treatment shows even greater irregularity as also does phosphoric acid, all of these trees having received the same annual applications of these elements. The data for 1944 reveal the same irregularities of levels of nutrients in relation to fertilizer treatment, but are more complex because of changes in fertilizer treatments made in 1944. The relationships of nutrient levels to yields in each of the years show similar inconsistencies.

From these facts it might be argued that it is futile to attempt any

control of leaf analysis in the case of fruit trees except in a general way such as by the determination of minimum values. But this argument takes into consideration only the relationships among nutrient levels, fertilizer applied and yields of all trees to one another in a particular season. It will be shown, however, that when the nutrition of each tree is considered individually a remarkably consistent picture is developed of the relation of mineral content and yields.

Nutrition of individual trees in successive seasons:—Fig. 1 shows at a glance that the magnitude of the displacements of the index values for leaf nitrogen, phosphoric acid and potash, respectively, from one season to the next for each tree differ considerably. The magnitudes of the displacements of the graphs of nitrogen in most cases are reciprocal to those of potash and phosphoric acid, a relatively small change in potash and also in phosphoric acid being accompanied by a relatively large change in nitrogen and conversely. The apparent exceptions to this rule (trees C4 and D32) are referred to later in this paper. Furthermore, these displacements are associated with differences in the production of fruit in each tree in such a manner that, *irrespective of changes in the fertilizer treatments in the years considered*, an increase in fruit production of a particular tree is accompanied by a relatively large increase in leaf nitrogen and a relatively small increase in leaf potash as well as phosphoric acid, and conversely. Moreover, with the exceptions mentioned, these displacements are roughly proportional to the differences in fruit produced by each tree in the two seasons. The conclusion appears to be inescapable that in investigations of fruit trees by leaf diagnosis, differences in fruit produced in successive years by a tree need to be taken into consideration in fixing either minimum or optimum nutrient values for the variety.

The displacements of potash, nitrogen, and phosphoric acid in trees C2, D2, C3, D3, D4:—The potash content of the leaves from these trees was low, and well below optimum in 1943. In 1944, accordingly, 5 pounds K_2SO_4 in addition to the regular annual additions of fertilizer shown in Table I were applied to these trees. The direction of the displacements show that irrespective of whether an increase in fruit production took place in 1944 relative to 1943 (trees C2, D2, C3, D3) or a decrease (tree D4) occurred, the content of potash is increased and that the increase as represented by the magnitude of the displacement is roughly inversely proportional to the differences in fruit produced by each of the trees in 1944 compared with 1943. The greatest displacement of the potash content (equal to 39.4 per cent of the value in 1943) occurs in tree D4 having a decreased production of 97 per cent, and the smallest displacement (equal to 2.2 per cent) occurs in tree C3 having an increased fruit yield of 281 per cent.

D2 represents a tree in which very little difference existed between the fruit produced in the two years. It is reasonable to conclude, therefore, that the magnitude of the displacement in this tree represents fairly closely the net effect of the increase in potash additions in raising the leaf content in potash.

The direction of the displacement of nitrogen in each case is also

upwards, showing that the content of nitrogen has increased in 1944 relative to 1943. The greatest displacement (equal to 27.7 per cent above the 1943 value) occurs in tree C3 having an increased yield of fruit of 281 per cent, and the smallest displacement (equal to 1.85 per cent of the 1943 value) occurs in tree D4 in which a decrease occurred in yield of fruit equal to 97 per cent. It should, however, be pointed out that the magnitude of the displacement in the latter case is probably negligible being in the upper limit of analytical error. Also it should be kept in mind that this tree has never received any dressings of nitrogenous fertilizers; whereas trees C2 and D2 have received 10 pounds $NaNO_3$, and trees C3 and D3, 5 pounds annually.

Although in the diagram (Fig. 1) the scale for phosphoric acid is larger than for nitrogen and potash, nevertheless, the magnitude of the displacements, although appearing smaller, is actually of the same proportion as those for potash and nitrogen. The direction of the displacements for phosphoric acid is also upwards in each case and the magnitude of the displacements is roughly inversely proportional to the differences in fruit produced by each tree in the years compared. The greatest displacement (equal to 24.4 per cent of the 1943 value) occurs in tree D4 having a decrease in yield of 97 per cent and the smallest displacement (equal to 5.3 per cent of the 1943 value) in tree C3 with an increased fruit yield of 281 per cent.

Displacements in relation to the optima:—Only in trees D2 and D4 has a marked displacement of the potash content nearer that of the optimum occurred. In D4 in which a large decrease in fruit production took place the potash content is now above optimum and in D2 in which there was only a small increase (.9 per cent) in fruit production the content of potash nearly reaches the optimum value. In the remaining three trees (C2, C3, D3), in which increases occurred in fruit produced, the potash content of the leaves, notwithstanding the addition in 1944 of 5 pounds extra of K_2SO_4, is still well below optimum. The conclusion to be drawn is that in years of relatively high production, 6 pounds (1 pound + 5 pounds) of K_2SO_4 to these trees is insufficient. This point, however, needs further investigation.

In these trees (C2, D2, C3, D3, D4) the phosphoric acid content of the leaves is displaced further from the optimum. In D4, the tree in which a marked decrease in yield of fruit occurred in 1944, the displacement from the optimum value is greatest (32.5 per cent above it).

In all the trees referred to above and which received 5 pounds K_2SO_4 additional to the regular annual dressings the nitrogen graphs are displaced nearer that of the optimum. The nitrogen content of tree C3, in which the greatest increase in yield occurred, is now nearly optimum (actually slightly higher); whereas the nitrogen content of the companion tree D3, in which the increase of yield is less, is still well below optimum.

The displacements of the graphs in tree C4:—Among the trees of relatively low vigor in rows 2, 3 and 4 this tree, which until 1944 has never received any nitrogenous fertilizers during its life history, is the lowest in vigor, and is characterized by an abnormally high

content of phosphoric acid in 1943, well above (60 per cent) that of the optimum value, and with a content of potash somewhat below (5.4 per cent) that of the value of the optimum, but very much higher than that of the trees already considered. Accordingly, in 1944 no potash was applied to this tree beyond the regular annual applications. The further change made was the addition of 10 pounds $NaNO_3$ and the omission of superphosphate in 1944 from the regular annual dressings. (Table I).

The data for 1944 indicate that accompanying a decrease in yield of 100 per cent from a relatively low yield of 7 bushels, the potash content has risen from a value a little below optimum to the optimum value, and nitrogen and phosphoric acid are displaced towards the optimum values. The balance between these elements has been improved, therefore, but although phosphoric acid has been omitted from the fertilizer the value is still much too high. Notwithstanding these facts no fruit was produced in 1944, because of scanty blossom bud formation associated with unbalanced nutrition in 1943. The apparent anomalous deviations of the displacements of nitrogen, phosphoric acid, and potash of tree C4 have their origin in the difference in the fertilizer treatment of this tree from those of the other trees in this row.

The displacements of the graphs for nitrogen, phosphoric acid, and potash in the high-vigor trees C31, D31, C32, D32:—Only in C32 was the production of fruit greater in 1944 than in 1943; and in the latter year the yield of this tree was lower than that of any of the other three trees. Although the succession of relatively high yields followed by lower yields and conversely has not been prevented by the changes in fertilizer made in 1944, this rhythm may have been modified. This is suggested by the fact that the reduction in yield of fruit is greatest in the tree (D31) to which no additional fertilizer was added in 1944. The reduction in yield of this tree is greater than that of its companion tree C31, the yield of which in 1943 was approximately the same as that of D31. It is possible too, from the evidence presented later that the yield of D32 would have been reduced more in 1944 but for the change made in the fertilizer to this tree.

The relationships of the displacement of the graphs of the respective elements to differences in yield of each tree in 1944 compared with 1943 are similar to those in the less vigorous trees, namely, relatively large displacements of the potash and phosphoric acid contents and relatively small displacements of nitrogen being accompanied by relatively large decreases in yield of fruit, and conversely.

Tree C31 was of relatively high productivity in 1943. The decline of 40 per cent in the yield the following year is accompanied by a displacement of the potash content of the leaves, equal to 17 per cent of the 1943 value, from a content nearly optimum to one 15 per cent above it, and a displacement (12 per cent) of the phosphoric acid content from below the optimum to reach that of the optimum in 1944. With reduction in the yield the addition of even 15 pounds of $NaNO_3$ has resulted in only a small increased displacement of nitrogen equal to 4.5 per cent of the 1943 value and still below the optimum.

Tree D31, the companion tree to C31, received only the regular annual dressings of fertilizer. The displacement of the graph for phosphoric acid is not so great as conformity to the rule would require in view of such a relatively large reduction in fruiting. Examination of the data among these trees does not reveal the reason for this.

The potash content, as in tree C31, is nearly optimum in 1943 and with reduction in fruiting is displaced 13 per cent above that of the optimum the following season. The nitrogen content is lower during both seasons than in that of the companion tree C31.

Tree C32: The nitrogen graph of this tree which received the highest application of nitrogen (20 pounds $NaNO_3$ in 1944) is displaced 11 per cent above its 1943 value to reach the value assigned to the optimum for this element; and is accompanied by an increase in yield of 57 per cent to the highest of any of the trees considered. The nitrogen content is now well above that of tree C31 which received 5 pounds less $NaNO_3$ in 1943, although the levels of nitrogen in 1943 were nearly the same in both trees.

The displacement of the potash content (1.6 per cent of the 1943 value) is negligibly small, being within the limits of analytical error.

Tree D32: This is the most vigorous tree of all considered in this investigation; albeit in the years under consideration this tree has been surpassed in yield of fruit by trees C31 and D31 in 1943, and by tree C32 in 1944.

In 1943 the potash content of the leaves was very low and much lower than those of the other three vigorous trees just considered, although fruit production in 1943 was only slightly below that of trees C31 and D31. For this reason and for another reason which need not concern us here, 15 pounds of K_2SO_4 were added in 1944 in addition to the regular annual fertilizer dressings.

The reduction in fruit (20 per cent) is much less than in trees C31 (40 per cent) and D31 (66 per cent). If the regular application (1 pound) of K_2SO_4 had been made, it would be expected on the basis of results obtained that this relatively small decrease in production would be accompanied by a smaller displacement of potash than that which actually occurred — smaller for example than in trees C31 and D31. Actually the displacement is somewhat greater; it is reasonable to suppose, therefore, that this is an effect of the relatively enormous K_2SO_4 additions, which appears also to account for the smaller displacement of nitrogen than the rule requires.

Indications given by the elements considered collectively as a unit: —Having considered the relations of fertilizer and yield to changes in the leaf content of nitrogen, phosphoric acid, and potash each separately, the data can be explored to ascertain what additional indications are given when consideration is given to the relationship among fertilizer, fruit production, and the leaf content of each tree with respect to the fertilizer elements collectively (3).

In the case of herbaceous plants our investigations have consistently shown that a fertilizer intervenes in the nutrition of the plant to affect a change either in (a) the intensity of nutrition or (b) the quality of nutrition as represented by the NPK-equilibrium or in both,

simultaneously. Yields follow a definite pattern in relation to these values. For reasons already given the relationship of fertilizer to yields of fruit trees is more complex and therefore the pattern followed would be expected to be less rigid than in herbaceous plants.

The intensities of nutrition, that is, the index expressing the sum of the values of the leaf content of nitrogen, phosphoric acid, and potash for each tree in each of the years 1943 and 1944 are given in the top left hand corner of Fig. 2. In every case the resultant intensity is greater in 1944 than in 1943, even when as in the case of tree D31 no change in fertilizer treatment occurred. These differences in intensity represent the composite displacements of all three of the elements considered in each case. Except for certain trees one would expect from the facts already elucidated that these differences would be relatively constant, and this is the case. The reasons for the great deviations from the mean difference of 0.60 in trees C4, C32, D32 is apparent from the facts already revealed.

Tree	Intensity		Yield, bu.	
	1943	1944	1943	1944
C2	3.51	4.26	6.0	14.0
D2	3.78	4.45	12.4	13.5
C3	3.73	4.31	5.9	22.5
D3	3.56	4.13	11.5	17.0
C4	4.28	4.53	7.0	0.0
D4	3.92	4.56	17.2	0.4
C31	4.19	4.63	23.0	14.0
D31	4.16	4.53	23.6	8.0
C32	4.27	4.52	18.4	29.0
D32	4.06	4.36	22.0	17.5

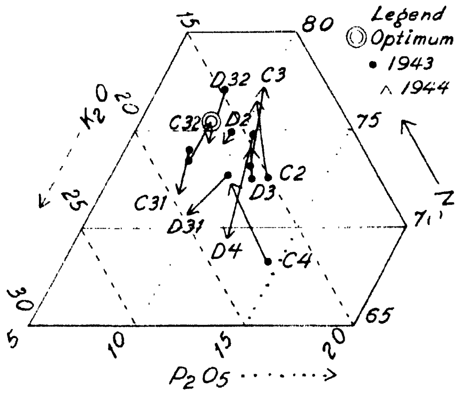

FIG. 2. Intensities of nutrition and displacements of the NPK-equilibrium in the two seasons shown in trilinear co-ordinates. The locus of the optimum equilibrium is indicated by an arrowhead within a double circle.

The displacements in the *NPK-unit* values for each tree are shown in Fig. 2 by lines joining the index for 1943 with that for 1944. It is seen that when the difference in yield is very small as in tree D2, the displacement is quite small. In trees C2 and C3 in which a large percentage increase (133 and 281 per cent respectively) and in C4 and D4 in which a large percentage decrease (100 and 98 per cent respectively) in yield occurred the displacements are relatively large, with intermediate displacements roughly proportional to the differences in yield in the case of the remaining trees except D32. The displacement of tree D32 is out of line with the others, being greater than would be expected from the relatively smaller differences in yield. The cause of this abnormality is apparent from the facts given already.

The locus of the optimum is shown by an arrowhead within a double circle. In those cases in which an increase of fruit production

trees (C2, D2, C3, D3) has occurred the locus is displaced nearer the optimum. The change relative to the locus of the optimum of tree D3 is small, as would be expected. The position of the locus of C3 in 1944, however, is further removed from the tentative optimum than would be expected, evidence that the relation of mineral nutrition to yields of fruit trees is not so simple as in the case of herbaceous plants.

A decrease in fruit production is associated in three cases with a displacement away from the optimum (D4, C31, D31), and in two cases, C4 and D32, towards the optimum. The reason for the abnormalities are apparent from the facts already given.

Summary and Conclusions

The nutrition during two successive seasons of certain mature York apple trees growing under different systems of soil management and fertilizer applications was examined by the method of foliar diagnosis. It was found that nutrition differed widely among the trees, whether they were similarly or differently treated; no consistent relation could be found, therefore, among fertilizer applications, yield, and nutrient content of the leaves sampled, in either of the two seasons considered separately.

By making comparisons between the nutrition of each tree individually between one season and the next, in relation to differences in yield and to differences which were introduced into the fertilizer treatments between the two seasons, however, it was found possible to discover consistent relations among the fertilizers applied, the nutrition of the trees as reflected in the composition of the dried leaves sampled, and the differences in yield between the two seasons. These relations are described fully.

It is apparent that the leaf content of nutrients in apple trees is influenced not only by the supply of these nutrients from the soil, but also by the individuality of the tree and by its condition with respect to fruit bearing. Consideration must be paid to these circumstances, if control of fruit production is to be obtained by means of leaf composition.

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Seasonal Absorption of Nutrient Ions by Orange Trees in Sand Culture

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INTRODUCTION

THE growing of plants directly in nutrient solutions or in pure sand to which such solutions are added has long been a useful method in studying various phases of plant nutrition in which the information sought cannot be obtained from plants growing in soil under field conditions. In the present investigation sand cultures were employed to study the seasonal intake by young orange trees of nitrogen, phosphorus, potassium, magnesium, and calcium from solutions containing in soluble form all of the nutrient ions known to be necessary. The method also offered an opportunity to obtain an accurate record of the amount of water used by the trees throughout the year.

Because of the artificial nature of the root environment in a sand culture as compared with a complex soil system, and for other reasons that will be brought out later, the data which follow might well prove misleading as a direct basis for fertilizer practice. The experiment was designed simply to determine from month to month the extent to which the orange tree absorbs the various nutrient ions here studied.

METHODS

Fourteen Parson Brown orange trees, budded 2 years previously in the nursery on rough lemon rootstock, were used for the experiment. The roots were washed completely free from adhering soil, after which the trees were replanted in January, 1942 in pure quartz sand in 8-gallon vitrified tile crocks. To each tree was fastened a piece of tar-paper roofing, so fashioned as to exclude rain water from the sand in the crock. These covers were easily removed for the purpose of applying nutrient solution or water. The crocks were supported on racks at a height of 2 feet from the ground. The bottom of each crock was provided with a drainage hole, in which was inserted an 8-inch length of glass tubing, by means of a one-holed rubber stopper. The lower end of the glass tubing was inserted in a 5-gallon glass bottle, which was placed immediately under the crock and which served to collect the drainage. A liberal amount of toluene was maintained in the drainage bottles to minimize bacterial action within the leached solutions until they were collected for analysis.

Two crocks, prepared in the same manner except that no trees were planted therein, were used as controls in a manner to be explained presently.

The first 6 months of feeding allowed the trees to establish new tops and roots and were also devoted to determining procedures to be fol-

[1]Acknowledgement is made to G. Hrnciar of the Station staff, and to erstwhile members, C. H. Brokaw, F. M. Cyst, and J. M. Harris, who at various times assisted with the analyses and the care of the trees.

lowed during the ensuing experimental period. At the end of this initial experimentation, the potted trees were divided into two sets of seven trees each, and one crock containing sand only was assigned to each set of trees as a control. The first set of seven trees was given nutrient solution daily, each tree receiving identical, carefully measured amounts of solution. The control crock, containing sand only, was given nutrient in the same amount. During periods of high transpiration enough water in measured amounts was also applied to keep the trees from wilting.

At the end of each 2-week period the crocks were flushed out thoroughly with 30 liters of water over an 8-hour period. This collected wash water was added to and thoroughly mixed with the original leachate and the total volume carefully determined. Two-liter samples from each total leachate were used in determining N, P, K, Mg, and Ca, calculating the total amount of each element leached from each crock. The difference between the amount of each of these elements found in the leaching from the control crock containing sand only and the amount in each tree leachate was calculated and represented that absorbed by the tree during the foregoing feeding period.

The second set of seven trees and the second crock containing sand only were given water only in the same manner as described above. At intervals of approximately 3 months they were fed for a period of 2 weeks, and the leachates collected and analyzed at the termination of the feeding period. This intermittent feeding was adopted to determine if trees which were "hungry," as it is assumed that grove trees sometimes become between applications of fertilizer, would have an appreciably different demand for the various elements than trees fed continuously.

The nutrient solution used was of the following composition:

Nitrogen	112	ppm from $Ca(NO_3)_2.4H_2O$
	56	ppm from KNO_3
	174	ppm from $NaNO_3$
Total N	342	
Potassium	143	ppm from KNO_3
	94	ppm from KH_2PO_4
Total K	237	
Phosphorus	75	ppm from KH_2PO_4
Magnesium	54	ppm from $MgSO_4.7H_2O$
Calcium	160	ppm from $Ca(NO_3).4H_2O$

In addition, minor elements were added to bring their concentrations in ppm to 1 of iron, 0.4 of manganese, 0.4 of zinc, 0.4 of copper, and 0.4 of boron.

Sufficient quantity of the above nutrient solution was used to insure an excess of all elements over that which the trees absorbed, as evidenced by the appreciable amounts of the elements determined in the leachate. The pH of the leachate disclosed a marked tendency of the nutrient solution to shift to the alkaline side due to a greater absorption of the acidic ions than of the basic ions. To prevent this shift toward alkalinity from progressing to the point where certain ions might be precipitated the pH of the nutrient solution, and of the tap water used

in watering, was adjusted to 4.5 with sulphuric acid. Even with this low starting point the pH of the leachate sometimes rose as high as 7.0

Records were kept as to time and amount of bloom and of flushes of growth, as well as bi-weekly measurements of trunk circumference, made at two marked points on each trunk. Girth increments were calculated by averaging the two trunk circumference measurements.

The trees were grown out of doors in full sunlight. At times when danger of freezing was imminent, all crocks were removed to a greenhouse until the danger of cold damage was past. Nicotine sulfate and oil sprays were used from time to time as required for insect control.

Temperature records in the root zone were kept by means of a continuously recording thermograph, the thermobulb being buried in the sand of one of the crocks.

Results

Tree Behavior:—The trees receiving continuous feeding grew normally, exhibiting healthy, dense foliage and a good bloom during January-February of the second season. This bloom was several weeks earlier than on orchard trees nearby, due probably to the continuous availability to the potted trees of ample water and nitrogen. No symptoms of deficiency appeared except for leaf patterns indicating a minor manganese deficiency in the spring, which soon disappeared. The leaves of the trees on intermittent feeding, as might be expected, developed typical symptoms of increasing nitrogen deficiency during the intervals without nutrients but these promptly disappeared after each feeding period. They were approximately 2 weeks later in blooming than the trees fed continuously.

In the second season in the crocks the continuously-fed trees produced a heavy crop of fruit, considering tree size, amounting to an average of 10.3 pounds of fruit per tree. The intermittently-fed trees produced an average of 6 pounds of fruit. The fruits from the two sets of trees were approximately equal in size, and no apparent difference existed in rind thickness or texture.

The continuously-fed trees gradually outgrew those intermittently fed in the amount of top growth. Fig. 1 shows the seasonal increase in trunk circumference of the two sets of trees. Although the most rapid rate of increase in trunk growth occurred between March 1 and August 10, a steady rate of increase continued throughout the balance of the year in the continuously-fed trees. It is clear that orange trees can and do increase in trunk caliper even during the so-called winter dormant period if they are well fed. Very little trunk growth occurred in the winter months in the case of the intermittently-fed trees.

Water Usage:—The difference between the amount of water applied and that which percolated through the pots to the collecting bottle represents an accurate measure of the transpiration rate. The relatively small loss due to evaporation from the sand surface under the paper cover of the crocks was corrected for by the results with the "treeless" control crocks. The seasonal transpiration rate for the continuously-fed trees is shown graphically in Fig. 2, together with the

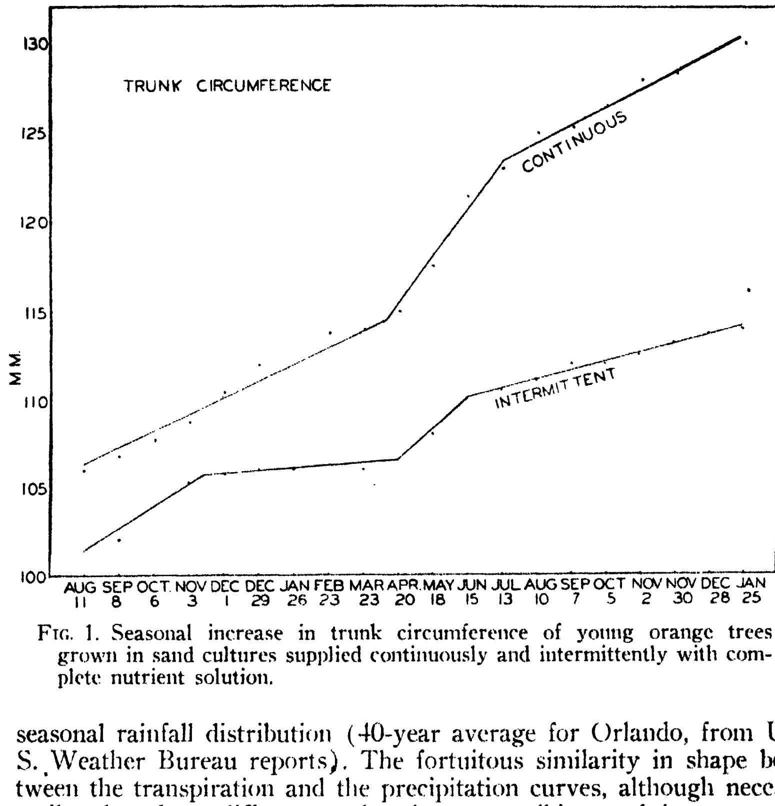

FIG. 1. Seasonal increase in trunk circumference of young orange trees grown in sand cultures supplied continuously and intermittently with complete nutrient solution.

seasonal rainfall distribution (40-year average for Orlando, from U. S. Weather Bureau reports). The fortuitous similarity in shape between the transpiration and the precipitation curves, although necessarily plotted on different scales, is very striking and is no small factor in the success and economy of production in Florida's citrus areas.

Nitrogen:—The absorption of nitrogen and of each of the other elements under study was determined independently for each tree for each 2-week period. In order to smooth out individual variations which naturally occur, and to simplify presentation, the absorption figures have been calculated as means of each group of seven trees by 4-week intervals and graphs made to show the seasonal intake over an 18-month period of development. The two arrows on each chart point to the dates of start of spring shoot growth and of full bloom, respectively.

Nitrogen was absorbed in appreciable amounts at all seasons of the year, although the rate of absorption was lowest during the months of January and February. A rapid increase in absorption is shown beginning in March, reaching a peak in April and May, at which time the rate was approximately double that during the January-February low (Fig. 3). It is worthy of note that the increase in rate of nitrogen absorption, as was true of the other ions also, did not begin until sometime after bloom. Of interest, also, is the observation that during the feeding period the nitrogen intake of the trees fed intermittently, rep-

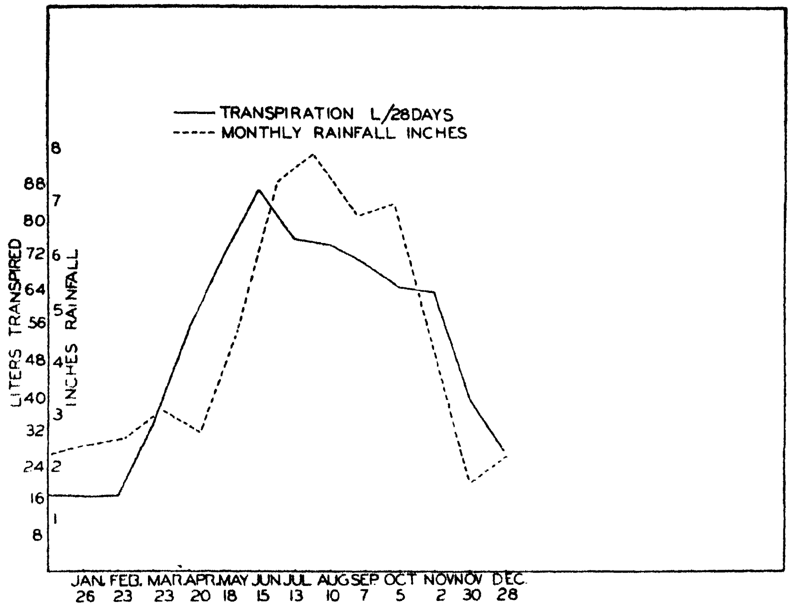

FIG. 2. Transpiration rate (liters per 28 days) of orange trees grown in sand culture, and mean monthly rainfall in Orlando area (40-year average, U. S. Weather Bureau).

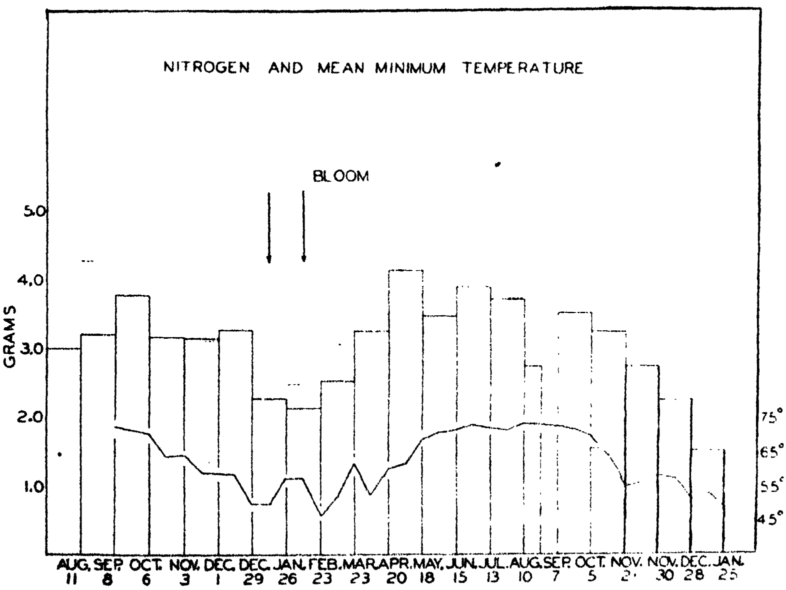

FIG. 3. Seasonal absorption of nitrogen by young orange trees grown in sand cultures with a complete nutrient solution supplied continuously (solid blocks) and intermittently (dotted lines). Mean minimum temperatures of the culture medium are also shown.

resented by the dotted lines on the graph, was in the same order of magnitude as the intake of the trees receiving continuous nutrient, suggesting that rate of nitrogen intake at any given period was not materially influenced by previous nitrogen consumption.

The mean minimum temperatures of the sand plotted with nitrogen intake make apparent that a fair correlation exists in which nitrogen absorption decreases with a lowering of the temperature. Chapman and Parker (2) report a similar relationship in their studies of nitrogen absorption by orange trees from water cultures. It is very doubtful that temperature *per se* is the only factor involved in this absorption, for if it were the relative rate of absorption of the other ions might be expected to follow closely that of nitrogen. It will be seen that there were points of marked dissimilarity in the behavior of the other nutrients even though the absorption of all ions decreased during the cooler months.

At one period during the experiment (August 24 to September 7) nitrogen was purposely omitted from the nutrient solution. It is interesting to note that following this exclusion, the intake of nitrogen was not accelerated to any appreciable degree with a return of this element to the solution.

Phosphorus:—A period of greatly decreased intake of phosphorus occurred during December, January, February, and March, followed by relatively high intake during the period April through November (Fig. 4). During the month of October in both years, phosphorus intake was greatly increased for some unaccountable reason. During the period of nitrogen omission (August 24 to September 7 of the second season) the phosphorus rate of intake was approximately half that of the preceding period, increasing in the period immediately following to a rate similar to that before withholding of the nitrogen. The sudden increased phosphorus intake in October occurred 4 weeks following nitrogen abstinence; however, such an increase also occurred at the same time of the previous year when nitrogen was supplied continuously.

Phosphorus intake of trees fed intermittently was generally of the same order of magnitude of those fed continuously, with some deviations.

Potassium:—The seasonal absorption of potassium showed a greater magnitude of fluctuation than nitrogen intake, being very low during the period December to February, and increasing rapidly following bloom (Fig. 5). During the first January, intake of this element ceased completely, there being some indication during this time that potassium was actually being returned to the solution from the roots; the amount, however, was of a very small order of magnitude and not consistent for all the trees in the crocks under continuous feeding.

During the period August 24 to September 7, when nitrogen was withheld from the nutrient solution, intake of potassium decreased sharply to 50 per cent of the absorption during the preceding 2-week period. When nitrogen was restored to the nutrient solution, the intake of potassium for the ensuing 4-week period increased sharply to a level 17 per cent greater than during the 4-week period prior to withholding

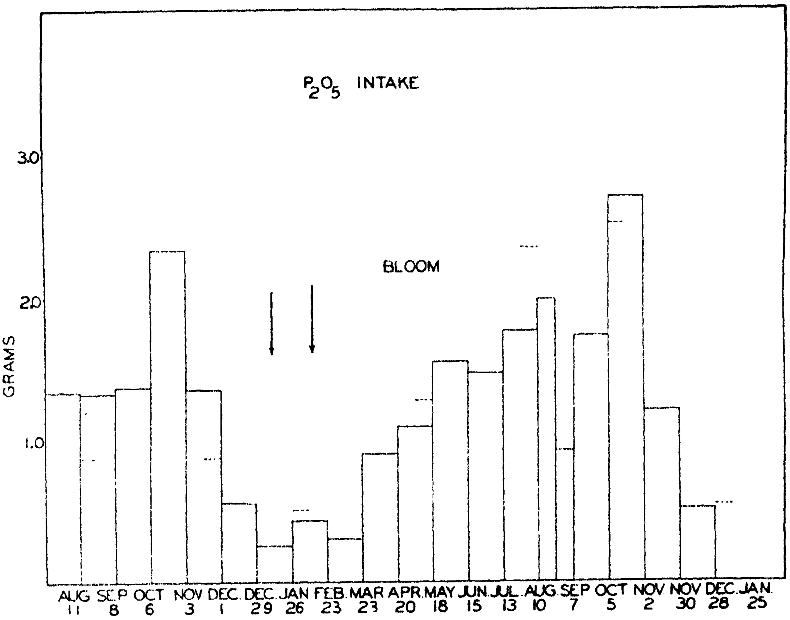

Fig. 4. Seasonal absorption of phosphorus (as P_2O_5).

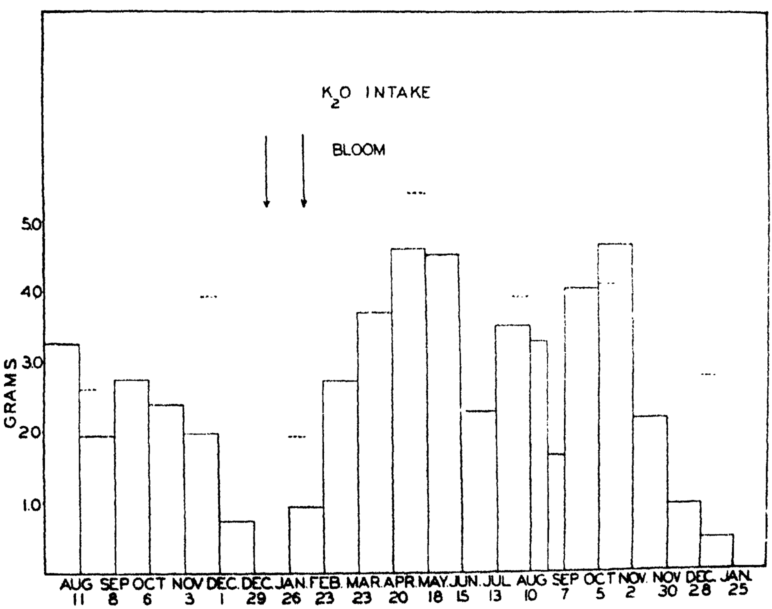

Fig. 5. Seasonal absorption of potassium (as K_2O).

the nitrogen and the following month it was 38 per cent greater. Based on behavior the preceding year, the rate of potassium intake during this period should be decreasing. It therefore appears that the rate of potassium intake was influenced both by (a) concurrent nitrogen absorption and (b) potassium hunger. The latter supposition is further substantiated by the intake of potassium during the feeding periods of the intermittently-fed trees, which, (with one exception) was greater than the potassium intake of continuously-fed trees during the same periods. The exception noted occurred during the time when potassium intake of the continuously-fed trees was stimulated by previously withholding nitrogen. Breazeale (1) has pointed out that the absorption of phosphorus and potash, but not calcium, is accelerated by the presence of nitrogen, in a study of seedling wheat plants grown in water cultures.

Magnesium:—The intake of magnesium was very low during the period November through February, increasing rapidly through the spring to a peak in late May and early June, and then decreasing to November (Fig. 6). During three of the 4-week periods (November through January, the first year) no magnesium was absorbed, and like potassium, there was some evidence of a return to the sand of slight amounts of this element. This apparent excretion of magnesium and potassium can possibly be accounted for by the normal dying of some root tissues which lose their powers of ion retention and therefore small amounts of these elements diffuse continuously, the amount becoming recordable only when the live roots were absorbing none of the elements in question. Haas and Reed (3) mention excretion of potas-

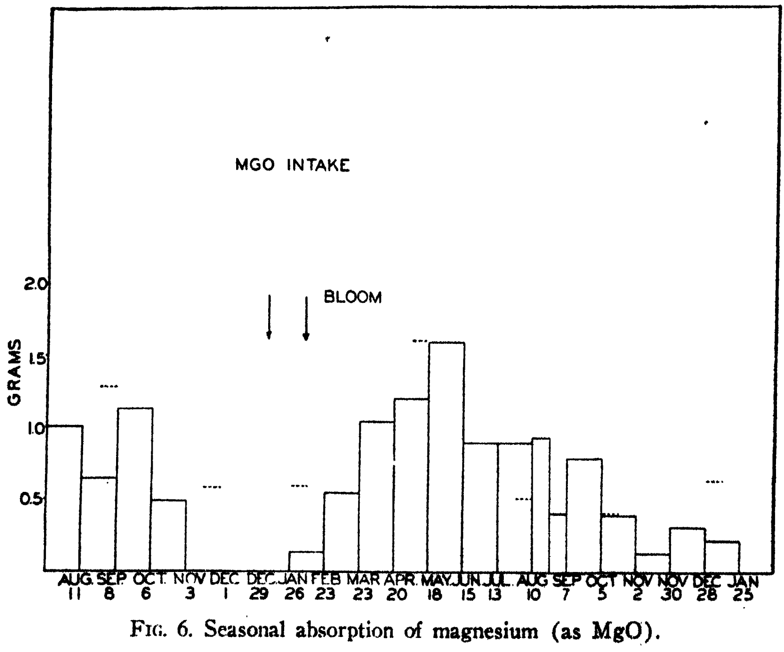

FIG. 6. Seasonal absorption of magnesium (as MgO).

sium into nutrient solution by citrus seedlings when the potassium becomes very low.

During the period August 24 to September 7, when nitrogen was withheld, the intake of magnesium was suppressed to half of its magnitude before and after. Following resumption of nitrogen feeding, there was a normal intake of magnesium again.

Intake of magnesium by the intermittently-fed trees during the feeding periods is of interest. During warm weather, when this element was being absorbed readily by the continuously-fed group of trees, the rate of magnesium intake by the intermittently-fed group was about the same. However, during the colder weather when magnesium intake was at a very low level by the continuously-fed group, it was still being absorbed in appreciable amounts by the trees which were intermittently fed. This would suggest that some absorption of magnesium may occur at any period of the year if a tree deficit for this element exists, although during the summer it is certainly much more readily absorbed.

Calcium:—The absorption of calcium in comparison with the other ions studied was relatively high, the period of greatest intake occurring from April through November. As in the case of nitrogen, appreciable although reduced amounts of calcium were absorbed throughout the winter months. A good degree of correlation was noted between calcium intake and transpiration as shown in Fig. 7, when the two are plotted together.

Analytical data (4) have revealed that calcium tends to increase in the leaves of citrus trees throughout their entire lives, and that such

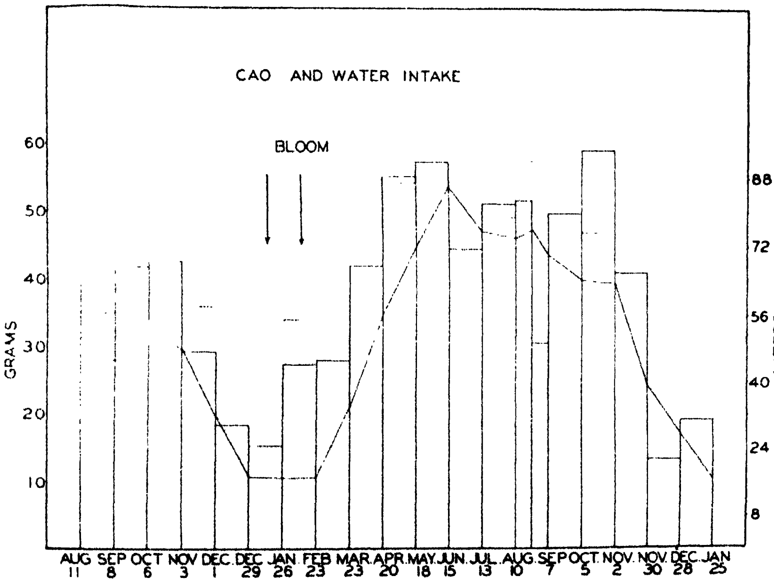

FIG. 7. Seasonal absorption of Calcium (as CaO). The continuous line showing the water intake suggests a relationship between calcium intake and transpiration.

accumulation is more pronounced in Florida during the summer months, which is the period of greatest rate of transpiration.

Absorption ratios:—The proportions of N, P_2O_5, K_2O, MgO, and CaO absorbed in each 4-week interval during the experiment are presented in Table I. Nitrogen is placed at unity, and all other fertilizer ingredients are calculated on this basis. From the table it can be seen that with nitrogen equal to 1, the P_2O_5 absorption varied from 0 to an upper limit of 0.83; K_2O varied from 0 to 1.29; MgO from 0 to 0.46; while CaO varied between 0.56 and 1.78 as lower and upper limits, respectively. In general, relatively high ratios of the other nutrient elements to nitrogen absorbed occurred during the warm months and low ratios during the colder months. Absorption ratios for the entire period of the experiment, calculated from the total absorption of each of the ions in the order N, P_2O_5, K_2O, MgO, and CaO were found to be 1–.41–.88–.21–1.30 for the trees fed continuously, and 1–.35–1.07–.24–1.26, respectively, for the trees fed intermittently. The ratios for the total absorption during the last 12 months of the experiment, from January 26, 1943, through January 25, 1944, in which period the trees bloomed and matured a crop of fruit, were 1–.38–.98–.23–1.36 (with N=1) for these ions in the order given above. In considering the absorption ratios for any given period the actual amount of nitrogen absorbed during that period should also be kept in mind since the other elements are only relative to the amount of nitrogen.

TABLE I—SEASONAL RATIOS OF NUTRIENT ABSORPTION (WITH NITROGEN GIVEN A VALUE OF 1)

Four Weeks Ending	N	P_2O_5	K_2O	MgO	CaO
Aug 11	1	0.45	1.08	0.33	1.31
Sep 8	1	0.41	0.61	0.20	1.08
Oct 6	1	0.37	0.73	0.30	1.11
Nov 3	1	0.73	0.75	0.15	1.35
Dec 1	1	0.43	0.63	0.00	0.93
Dec 29	1	0.17	0.22	0.00	0.56
Jan 26	1	0.11	0.00	0.00	0.67
Feb 23	1	0.20	0.43	0.06	1.27
Mar 23	1	0.12	1.08	0.21	1.11
Apr 20	1	0.28	1.13	0.32	1.29
May 18	1	0.26	1.11	0.29	1.33
Jun 15	1	0.44	1.29	0.46	1.63
Jul 13	1	0.43	0.68	0.26	1.30
Aug 10	1	0.54	1.08	0.28	1.57
Sep 7	N omitted	—	—	—	—
Oct 5	1	0.49	1.16	0.22	1.40
Nov 2	1	0.83	1.48	0.11	1.79
Nov 30	1	0.44	0.79	0.05	1.48
Dec 28	1	0.23	0.43	0.14	0.58
Jan 25	1	0.00	0.31	0.14	1.26
Ratio of total for entire period	1	0.41	0.88	0.21	1.30
Ratio of total for fruiting year	1	0.38	0.98	0.23	1.36

DISCUSSION AND SUMMARY

A record of monthly absorption of water, N, P, K, Mg, and Ca by two groups of Parson Brown orange trees grown in sand cultures is presented. One group was fed continuously with a nutrient solution containing all of the elements known to be essential to citrus, and the other group fed intermittently with the same nutrient solution, with water alone supplied in the intervals between feedings.

The rate of absorption of the various ions fluctuated greatly with the season of the year. In general absorption of water and of nutrients was low in the colder months reflecting, perhaps, the relatively quiescent period of tree activity. Following the resumption of new growth and bloom in the spring a rapid increase in the rate of intake of all ions occurred. In spite of somewhat similar seasonal trends the absorption of the various ions differed greatly in the extent of their fluctuations and in the time of cessation and resumption of their main absorption periods.

It is worthy of note that the increased rate of absorption of all ions in the spring did not begin until sometime after bloom. Because of the very low rate or complete absence of absorption of P, K, and Mg for a considerable period prior to bloom, it is apparent that blossom production and initial fruit set on these trees could have been influenced by these ions only through their absorption several months previously.

It is well known that trees absorb elements which are non-essential for their development and that they may also absorb amounts of essential elements in excess of their requirements, particularly if large amounts of the elements are available. There is some evidence that the orange trees on continuous feeding in this experiment may have taken in more nutrients than they could advantageously use. It was mentioned earlier that the continuously-fed trees produced an average of 10.3 pounds of fruit per tree, whereas the intermittently-fed trees averaged 6 pounds. The total absorption of all ions by the intermittently-fed trees was approximately only one-fifth that of the trees constantly supplied with nutrients. This difference in absorption was out of all proportion to the difference in yield or in tree growth between the two sets.

From the viewpoint of practical application of the findings in this report it should be borne in mind that important inherent differences exist between a soil system and the sand cultures used herein. Even Florida's light Norfolk soils exhibit a degree of ion fixation and base exchange which influence nutrient availability, whereas these factors are absent in pure sand cultures. In this connection, it is recognized that the concentration of individual ions in a nutrient solution may influence to some extent the degree of absorption of other ions and that therefore the picture of seasonal ion absorption presented here may not conform entirely with the absorption from a soil mass, or from a nutrient solution of different composition. It is recognized also that the fluctuation of temperature in the root zone of the sand cultures in this experiment were more extreme than would occur in the soil. Because of such differences, judgment and caution must be exercised in any attempts to interpret these findings in terms of orchard fertilizer procedures. However, the striking behavior of the trees with respect to seasonal nutrient uptake raises the question as to whether most of the present fertilization programs could not be made more efficient by varying the formula to comply more nearly with the seasonal ability of the trees to absorb the various ions and also thereby to avoid excessive loss by leaching of soluble nutrients during periods of low intake.

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Significance of the Alkaline Ash of Citrus Juices[1]

By WALTON B. SINCLAIR and DESIRE M. ENY, *University of California Citrus Experiment Station, Riverside, Calif.*

THE total acidity of citrus juices is ordinarily determined by titrating a known volume of juice with a standard solution of sodium hydroxide, with phenolphthalein as indicator, the result being expressed as citric acid. This value includes all the substances of an acidic nature in the juice that react with sodium hydroxide. It so happens, however, that in citrus fruits the substances reacting with sodium hydroxide are the organic acids, that is, the citric and malic acids. In other words, citric and malic acids account for nearly all of the acidity of citrus juices (3, 4, 5, and 6).

These organic acids exist in citrus juices in two forms, namely, as free acids, which can be titrated with sodium hydroxide, and as combined acids, or acids in combination with the cations in the juice. In citrus juices the free acids are always much greater in concentration than the combined acids. This does not minimize the importance of the combined acids, however; for these acids are important, not only in the physiology of the fruit, but also in certain problems of human nutrition.

The purpose of the present paper is to report the results of investigations on the amounts of organic acids combined with the cations in citrus juices (orange, grapefruit, and lemon), and to show that the combined acids measure their alkalizing capacity. These two values (combined acids and alkalizing capacity) are determined from the alkalinity of the juice ash.

The alkalizing capacity is defined as the degree to which citrus juices form base elements when they are digested by the human body, liberating mineral elements (or cations) to form salts with the fixed acids, and usually resulting in making the urine more alkaline. Foods that so function are base-forming foods, and are considered as foods which give an alkaline ash. Usually, but not always, the base-forming foods raise the alkalinity (pH) of the urine.

ALKALINITY OF ASH AS A MEASURE OF THE CATIONS COMBINED WITH THE ORGANIC ACIDS

During the ashing process of citrus juices the organic materials are burned off leaving the equivalent mineral elements (cations) as carbonates, oxides, and some sulfates and phosphates. The amount of standard acid required to neutralize this ash represents the alkalinity and it is a fair measure of the cation content combined with the organic acids in the juice. Juices of mature lemons and grapefruits have approximately the same concentration of combined acids; that of the orange is significantly greater. The specific cations combined with the organic acids have not been determined. It is highly probable, however, that the citrates (salts) are present in the juice as the potassium acid

[1]Paper No. 540, University of California Citrus Experiment Station, Riverside, California.

citrates, since the potassium concentration accounts for 60 to 70 per cent of the total cations.

It can be seen from Table I that the base-forming capacity of mature grapefruit and lemon juices is on the average of 204.9 mgs of citrus acid or 3.2 milliequivalents per 100 cc of juice. These values represent the amount of acid which is neutralized in 100 cc of juice by cations. The base-forming capacity of orange juice is greater with an average of 296. 4 mgs of citric acid or 4.6 milliequivalents per 100 cc.

TABLE I — THE COMBINED ORGANIC ACIDS (AS CITRIC) IN CITRUS JUICES

Sample	Grapefruit		Lemon		Orange	
	Mg/100 Cc	Me*/100 Cc	Mg/100 Cc	Me/100 Cc	Mg/100 Cc	Me/100 Cc
1	196.0	3.1	213.0	3.3	292.0	4.6
2	208.0	3.2	208.0	3.2	301.0	4.7
3	202.0	3.1	213.0	3.3	307.0	4.8
4	204.0	3.2	194.0	3.0	294.0	4.6
5	196.0	3.1	215.0	3.3	288.0	4.5
Mean	201.2	3.1	208.6	3.2	296.4	4.6

*Me = milliequivalents.

It is apparent that the amount of organic acids which combines with the cations to form salts depends upon the concentration of available cations. The amount of free organic acids available for salt formation in the juice would never be a limiting factor, for the acid concentration at all times would be many times greater than the total mineral content. Although the total mineral content of a given sample is obtained from the ash, the concentration in the juice is correlated with the mineral elements absorbed by the roots during fruit development. Soil conditions favorable for increased absorption of minerals by the plant could produce an increase in the total ash of the fruit, thereby increasing the alkalinity of the ash in the juice. The total ash content of the fruit can apparently be increased only to a limited extent by differences in cultural conditions. The total mineral constituents in vegetative portions of most plants usually respond to climatic and soil changes more readily than do those in the fruit.

Experimental data published elsewhere (3, 4, 5 and 6) showed that, if it were possible to double the amount of cations in the juice by fertilization of the trees, the resulting increase in total acids neutralized would be only 3.5, 10:0, and 15.0 per cent for lemons, grapefruits, and oranges, respectively. This is based, of course, on the supposition that the alkalinity of the ash was increased in proportion to that of the normal juice. These relatively large changes in combined acids would cause a very slight increase in pH owing to the high buffer property of the juice.

ALKALINITY OF ASH AS A MEASURE OF ALKALIZING CAPACITY OF JUICE

Extensive nutritional research has shown that citrus fruits (and others, such as tomatoes, pears, peaches, and apricots) contain base-forming elements, which, when eaten and digested by individuals have the power to neutralize the fixed acids of the body and, consequently,

raise the pH of the urine. Although these fruits are acid in reaction, the degree of acidity or basicity in the metabolic process depends upon the extent to which the organic acids are oxidized or burned as a source of energy in the body, setting free minerals (mostly potassium) to combine with the acid residues in the urine. Most fruit acids, especially citric acid, are nearly completely oxidized in the body. Citrus juices, therefore, do not exhibit an ultimate acid effect, but reduce the acidity of the urine because of the alkaline ash produced during metabolism. This factor has been definitely established by the investigations of Blatherwick and Long (1). The rapid rate at which citric acid is metabolized was demonstrated by Kuyper (2) in experiments which showed that the alkali formed from ingested sodium citrate was excreted in the urine at approximately the same rate as that from sodium bicarbonate. From these considerations, the conclusions can be drawn that, in addition to a small amount of the phosphates which exist in the acid form in the juice, the alkalinity of the ash is a measure of the base-forming capacity of the juice, as well as a measure of the cations combined with the organic acids.

The fractions of the total cations combined with the organic acids in the juices of mature Valencia and navel oranges and grapefruit are compared in Table II. The total cation content of the different juices is represented by the sum of the calcium, magnesium, potassium, and sodium values, expressed in milliequivalents per 100 grams of juice. Undoubtedly, other cations are present in the juice, but in such microquantities as to produce only a slight effect on the values given. Grapefruit juices had 57 per cent of their total cations combined with the organic acids, and Valencia and navel orange juices had 71.47 and 72.94 per cent, respectively. The remainder of the cations are combined in the juices with the inorganic anions, which include sulfates, chlorides, nitrates, and part of the phosphates. The titration curve of phosphoric acid demonstrates that approximately 34 per cent of this acid is in the salt form (KH_2PO_4) at pH 4.6. Since the juices of mature grapefruits and oranges have a pH of approximately 3.0 to 3.7, 25 per cent of the total phosphorus is in the salt form. In lemon juice, which has a pH of 2.1, 12 to 15 per cent of the phosphorus exists as a salt.

TABLE II — CATIONS IN ORANGE AND GRAPEFRUIT JUICES

Fruit	Total Cation Content	Cations Combined with Organic Acids		Cations Combined with Inorganic Anions
	Me/100 Gms	Me/100 Gms	Per Cent (of Total Cation)	Me/100 Gms
Valencia orange	5.96	4.26*	71.47	1.70
Navel orange	6.06	4.42*	72.94	1.64
Grapefruit	5.35	3.05	57.00	2.30

*These values are slightly lower than the approximate alkalizing capacity reported for orange juice (5 milliequivalents per 100 grams) in the standard texts on human nutrition.

SUMMARY

The organic acids, citric and malic, account for the total acidity of citrus juices (orange, grapefruit, and lemon). These organic acids

are present in the juices in two forms: (a) as free acids (titratable acidity) and (b) as combined acids (organic acids combined with cations and not indicated by titration). The combined acids and the alkalizing capacity of the juices are determined from the alkalinity of the juice ash. This means that the alkalizing capacity is equivalent to the amount of cations combined with the organic acids in the various juices. The alkalizing capacity of the juices is related to the total ash content. The amount of cations combined with the organic acids, plus the small portion of the acid phosphates represent the alkalizing value of the juice.

From the standpoint of human physiology, the alkalizing capacity of citrus juices depends upon the rate at which citric acid is burned by the body during metabolism, liberating the cations to combine with the acids internally, and usually resulting in a more alkaline urine. It so happens that citric acid is oxidized to a great extent by the body, and thus leaves an alkaline ash equivalent to the combined acids in the juice.

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Problems in the Dehydration of Orange Juice

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A PROCESS has been developed employing vacuum diffusion for the dehydration of orange juice to a virtually anhydrous powder. The powder is extremely palatable and should go far in increasing the distribution of orange juice to segments of the world's population now deprived of this valuable food. The dehydration can be stopped short of the powder state to make a concentrate which can be sold as a frozen food. This frozen concentrate when reconstituted with three times its volume of water closely approximates fresh juice.

The purpose of the present paper is to discuss the process and describe some of the problems involved, as well as to present data in the hope that some duplication of effort by other workers may be avoided.

Orange juice is screened and circulated at a temperature of 55 degrees F through concentrators where the water is evaporated under vacuum until the concentration reaches 50 to 60 per cent solids. At this point some of the concentrate is further dried to powder, some is stored at 0 degrees F and the remainder is blended with fresh juice to approximately 44 per cent solids. This latter operation restores volatiles lost by vacuum concentration. The addition of fresh juice to obtain optimum quality was developed by Dr. L. G. MacDowell of the Florida Citrus Commission. A public service patent for this procedure has been requested by the Commission.

The concentrate is introduced into large vacuum driers where it is dried to a powder containing not more than 1.5 per cent moisture at temperatures in the order of magnitude of room temperature. Pressures obtained in this step go as low as a few microns with 100 microns typical of the end of the cycle.

In the drying of the concentrate to powder, the driving force for movement of water vapor in the vacuum is a trap in series with the pumping line. This is held below −50 degrees F and its surface is continually renewed by rotating scraping blades. In this way maximum effectiveness is obtained from the refrigeration since ice which is a heat insulator is never allowed to accumulate on the condensing surface.

The powder and concentrate are readily rehydrated to a drink containing 12 per cent solids. This serves to introduce the horticultural aspects of the problem. The processor buys juice having from 9 to 15 per cent solids but sells on a fixed solids basis. Orange varieties having high solids content and capable of high yields would be of great interest. Perhaps the time will come when oranges are sold on a solids basis. This would certainly encourage further genetic research.

Extremely thorough work by Paul L. Harding (3, 4) and coworkers on seasonal changes in Florida oranges forms a basis for planning operational schedules of a dehydrating plant. It gives data on solids, acid, ascorbic acid, pH, and ratio of total soluble solids to

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[1]Citrus Research Laboratory at Plymouth, Florida.

acidity as a function of time and rootstock. The work is a guide to intelligent blending of orange juice which should go far in making for uniformity in taste and in maintenance of a relatively high level of ascorbic acid. Stahl (9) has made blends of orange concentrate containing, for example, 25 per cent Valencia and 75 per cent Parson Brown or Hamlin juice. The taste is superior to the Parson Brown or Hamlin alone and, therefore, these early season juices of very high ascorbic acid content, which are rather thin in taste, can be advantageously used with late Valencia which is full-bodied but rather low in ascorbic acid. Harding's taste studies show that a ratio of total soluble solids to anhydrous citric acid of about 10 or 10.5 to 1 and above is necessary in order to have maximum palatability. Here again is a useful tool in intelligent blending and scheduling.

Concentrate made in this laboratory of a mixture of Hamlin and Parson Brown juice was of higher palatability than the initial juice, probably because it was reconstituted to 12 per cent soluble solids as compared to an initial value of 9.5 per cent. It had more "body".

Studies will have to be made over several seasons before precise recommendations on blending can be made, however.

Orange juice is recognized as a rich carrier of vitamin C. Table I summarizes changes in ascorbic acid in production of orange concentrate having 50 to 60 per cent solids. The mean retention was 96.6

TABLE I—Changes in Ascorbic Acid in Manufacture of Orange Concentrate Having 50 Per Cent Solids

Run Number	Ascorbic Acid (Mg/Gm) Dry Basis		Percentage Recovery
	Fresh Juice	Concentrate	
A1	4.11	3.94	95.8
A2	4.53	4.38	96.6
A4	5.02	4.74	94.5
A6	4.84	4.76	98.4
A7	4.75	4.72	99.4
A8	4.29	4.22	98.4
A9	4.48	4.29	95.8
A10	4.37	4.05	94.8
A11	4.39	4.13	94.1
A12	4.26	3.86	90.6
A14	3.91	4.01	102.0
A15	4.12	4.10	99.3
A16	4.65	4.65	100.0
A17	4.12	4.03	97.8
A18	4.25	4.11	96.7
A19	4.23	4.19	99.1
A21	3.99	3.77	94.5
A22	4.33	4.14	95.7
A23	3.99	3.92	98.2
A24	4.18	3.64	87.0
A25	4.16	4.07	97.8
A26	4.24	3.96	93.4
A27	3.71	3.79	102.0

Mean percentage retention of ascorbic acid in concentrate = 96.6 per cent.

per cent. Data for six dehydrations of juice to powder gave the following recoveries in percentage, 97.3, 98.8, 92.3, 95.4, 96.6, 99.0. The mean retention was also 96.6 per cent. It should be emphasized that these are pilot plant data representing in some cases purposely drastic treatments for experimental reasons. The temperatures employed were

often greatly in excess of, and the times of treatment as much as several hundred per cent higher than, the current technique used in the pilot plant and the procedure used in the newly constructed production unit, Vacuum Foods Inc., formerly Florida Foods, Inc. Two values of 102 per cent recovery were obtained. It is felt that they arise from sampling error.

The stability of flavor and ascorbic acid in any processed orange juice product is of tremendous significance. The vitamin C level when the purchaser consumes canned, concentrated or powdered juice is important from the human nutrition viewpoint. Moore, Wiederhold and Atkins (7) report for canned orange juice retentions of 81.7 and 95.1 per cent of the initial ascorbic acid after 6 months storage at 80 degrees F and 40 degrees F, respectively. The method of analysis used was the standard indophenol procedure (2). Four batches of orange powder made by the vacuum diffusion process were stored 6 months at about 80 degrees F. The average retention of ascorbic acid was 99.2 per cent. The powders were loose and fluffy, they rehydrated easily, and had a good taste when opened. Moore, Atkins, Wiederhold, MacDowell and Heid (6) in a review of proposed methods of making powder and concentrate quote Stevens (11) as saying that orange juice concentrate stored at —5 degrees F for 6 years retained over 90 per cent of its ascorbic acid. Tests in this laboratory (Plymouth) for shorter periods confirm the above finding.

Where a great many determinations of ascorbic acid are being made a rapid method of analysis is highly desirable. Stevens (10) has shown that for citrus juices iodate titration values closely check indophenol titrations. Ballentine (1) has also reported this and gives a slightly simpler technic. Table II gives a comparison of values obtained in this laboratory by the Ballentine procedure and the widely used indophenol titration.

It will be seen that the iodate values for the first three samples are approximately 1 per cent higher than the values obtained with in-

TABLE II—Ascorbic Acid in Mg/gm

Sample	Indophenol Titration	Iodate Titration	Photometric Analysis
Fresh juice	0.469	0.472	—
	0.471	0.474	—
	0.471	0.474	—
	Average 0.470	0.473	—
Orange concentrate	2.04	2.09	—
	2.06	2.05	—
	2.04	2.05	—
	Average 2.03	2.06	—
Orange powder	3.89	2.96	—
	3.94	2.96	—
	3.92	3.94	—
	Average 3.92	3.95	—
Orange powder No. 14 stored several months at 100 degrees F	2.59*	2.69	2.59*
Orange powder No. 33 heated to 100 degrees F for a week	2.70*	2.87	2.67*

*Data obtained by Bernard L. Oser, Food Research Laboratories Long Island City, N. Y.

dophenol. In order to determine whether powder that had been subjected to very severe aging tests gave a fictitiously high value careful analyses of two samples of powder were made by the elaborate method of Hochberg, Melnick and Oser (5) which minimizes errors caused by reducing substances other than ascorbic acid. Powder stored at 100 degrees F for a week or for several months had ascorbic acid levels 6 and 4 per cent higher respectively by the iodate method compared to indophenol titration. The photometric method, which includes dehydroascorbic acid, gave analyses within 1 per cent of the indophenol titration values.

At room temperature the retention of flavor in orange powder is good. Of course, a product containing high amounts of fructose does not retain excellent flavor at 100 degrees F for many weeks, especially if amino acids are also present. The use of 100 degrees F constitutes, therefore, an accelerated aging test. The flavor retention in the powder at 75 to 85 degrees F is so good, however, that it constitutes one economic argument for its production in spite of costs higher than canned juice. The results of hundreds of taste tests of new and aged powder are almost universally expressed as "excellent, not quite as good as fresh juice but far superior to canned juice."

It may be of interest to list here several of the technics employed in this laboratory in stability and drying rate studies. Water content changes are important in both the above. Since some reactions involving sugars are accompanied by decrease in water (hydrolysis of disaccharides) while others release water (amino acid — sugar reactions and degradation of monosaccharides) one can obtain clues as to reactions involved by accurate measurement of changes in water content. Moisture determinations dependent upon complete removal of water by vacuum drying were found to be inadequate because of (a) excessive time required to reach constant weight and (b) breakdown of the material at the high temperature needed, 60 degrees C. The measurement of the equilibrium vapor pressure over powder as an index of water content was studied. The pressures are correlated with the amount of water but the manipulations are very delicate and the time to reach equilibrium was often as long as an hour. The Fischer method (12) was found to give highly reproducible results after either storing a sample overnight in anhydrous methanol or heating it 20 minutes at 55 degrees C. A simplified titrimeter for this analysis designed by Glenn Mellen of this company was made at cost of less than 5 dollars and was completely satisfactory. This is less than 10 per cent of the cost of a commercial titrimeter, primarily because only current measurement is involved instead of potentiometric. Briefly, it consists of a Triplet 0–200 microampere meter, a 1.5-volt flashlight battery and resistors which impress a potential of 15 millivolts across two platinum electrodes in the analytical solution. When the titration is complete the current drops from 75 to 100 microamperes to zero.

Total and reducing sugars are analyzed by a modification of Scales technic (8). Data on water and sugar changes will be reported elsewhere. Preliminary data from five storage runs show that samples having 1.1 or less per cent of water initially experience increases of

approximately 30 per cent after 3 weeks at 100 degrees F. These are followed by very slight changes up to 9 weeks. Samples held at 80 degrees F show slight but definite increments (3 to 15 per cent) after 3 weeks, beyond which time the changes are very much less. After 25 weeks at 80 degrees F the water content was within 10 per cent of the value obtained at 3 weeks. Preliminary data on changes in total and reducing sugars have shown no notable changes. Titrable acidity and pH are usually followed in storage studies but as yet no significant changes have been observed.

A great number of experiments have been run on a small laboratory scale instead of in the pilot plant. Two useful tools were at hand (Fig. 1) for drying an experimental concentrate and its control to a powder. One is a cabinet drier made in the shop consisting of a vacuum tight square box, 24 inches by 16 inches by 16 inches. It has a self contained pumping system capable of holding 20 microns pressure, a

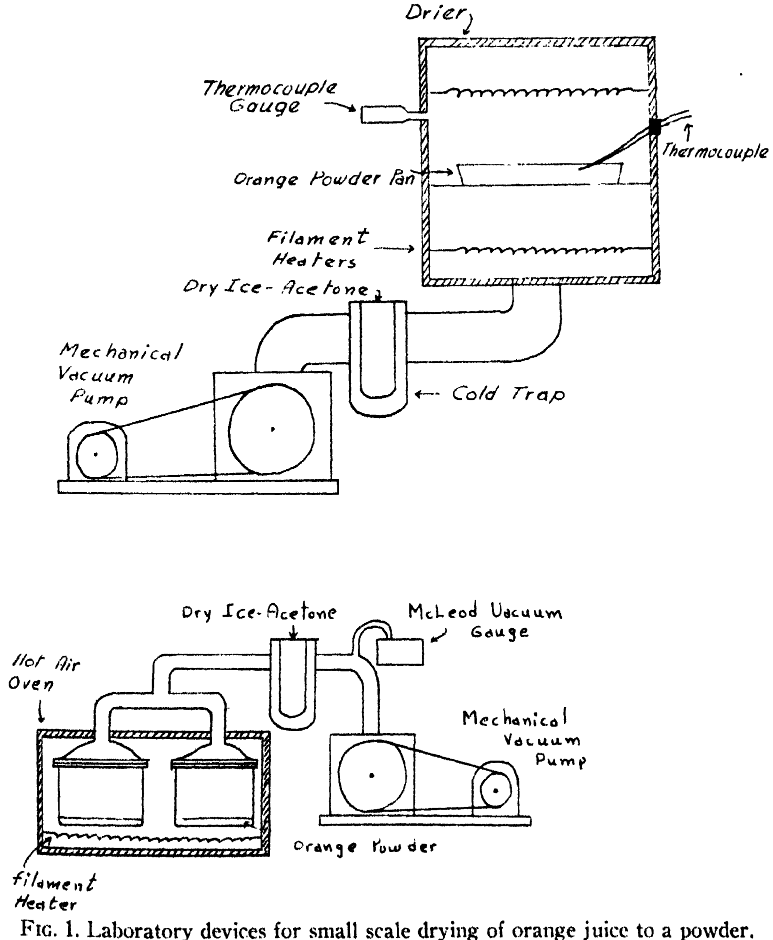

FIG. 1. Laboratory devices for small scale drying of orange juice to a powder. See text for explanation.

heating system controlled by a variable transformer, thermocouple selector switch for reading temperatures at various places inside the cabinet, a dry ice-acetone water vapor trap, and a "thermocouple gauge" panel by which pressures are read directly in microns on a dial. The gauge consists of a filament with an attached thermocouple. The heat input to the filament is kept constant. Variations in pressure cause variations in the temperature of the thermocouple, the current from which is read on a scale calibrated in microns pressure. The gauge employs the principle that removal of heat from a filament varies with the concentration of vapor molecules surrounding it. A McLeod gauge was used at times but the particular gauge employed is not accurate in the presence of water vapor above pressures of 100 microns. When total pressures were desired the thermocouple gauge could be calibrated for water vapor or the Alphatron gauge was used. This gauge reads directly in pressure from one micron to 10 millimeters of mercury and from a graph up to one atmosphere. It has a radium source of alpha particles and the ionization current reaching a grid is directly proportional to the molecules of vapor present since the emission of alpha particles is constant.

A second device was made (See Fig. 1). While of small capacity it was found to be decidedly valuable. It consists of two pyrex desiccators with standard taper female fittings at the top (also called vacuum distilling apparatus — Central Scientific catalog No. 12910). Into each was fitted a manifold one end of which was tapered to ¼ inch and was sealed by pressure tubing and clamps. Thermocouples could be introduced through the tubing. The rest of the manifold was 1.5 inches in diameter and led into a common copper pipe at right angles to the manifolds which in turn was in series with a dry ice trap and a vacuum pump. The two desiccators were thus in parallel and were totally inclosed in a small Cenco thermostatically controlled oven. The external temperature could then be adjusted and both vessels reached the same temperature at the same time. Any available pressure reading device could be used. In this small drier differences in drying rates caused by different treatments of the juice could be observd. Control runs showed that conditions could be closely duplicated so that two separate dehydrations of a concentrate had points on a drying curve that never deviated by more than 0.1 per cent water from each other.

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Effects of Cross-Pollination, Self-Pollination, and Sib-Pollination on the Dropping, the Volume, and the Kernel Development of Pecan Nuts and on the Vigor of the Seedlings

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Factors relating to the fertilization of the egg cell and the consequent development of the embryo and fruit are of economic significance in many plants, and the literature dealing with this subject is extensive. In the pecan [*Carya illinoensis* (Wang.) K. Koch], Morris (4) reported a good set of nuts by self-pollination in eight varieties; Adriance (1) found no evidence of self- or cross-incompatibility of pollen and pistil; Hamilton (2) found that the peak in dropping of open-pollinated nuts coincided in every case with that of bagged, unpollinated nuts of the same varieties, thus indicating that not all of the stigmas were pollinated under orchard conditions or else that egg fertilization did not occur in many of the pollinated flowers; Romberg and Smith (5) found that heavy applications of pollen to receptive stigmas of the Burkett variety caused greater percentages of the nuts to drop shortly after the applications, as well as during the period of heavy dropping of unpollinated nuts, than did light applications; Woodroof *et al.* (7) reported that the "May drop" apparently is associated with lack of fertilization in the ovule. They stated that part of the summer drop is due to embryo abortion. No report of differences in the effects of different pollens on the characteristics of pecan nuts has come to the writer's attention, but McKay and Crane (3) reported conclusive evidence of heterosis in the chestnut.

During the seasons 1934–1937, inclusive, the writers made preliminary studies on compatibility of pollen and pistil in pecan orchards near Austin, Texas, in which the set of nuts was recorded immediately after the drop of unpollinated nuts. The data from these studies, which included self-pollination, failed to show statistically significant evidence of incompatibility in the varieties used, but there were indications that selfing might increase the percentages of poorly developed nuts. Hence, experiments were conducted during the seasons 1941–1943, inclusive, to obtain more information on the effects of self-pollination compared with cross-pollination on nut development as well as on the set of nuts.

Methods and Procedure

Flowers of selected varieties growing in orchards near Brownwood, Texas, were bagged and pollinated according to the technic described by Smith and Romberg (6). All comparable pollinations for each variety were made on the same day and were replicated sufficiently for adequate sampling of flowers. Some preliminary pollinations with mixtures of two varieties of pollen were made in 1942, and were repeated on a larger scale in 1943, the object being to determine whether selectivity of pollen was apparent in egg fertilization. In addition to the strict selfing and crossing of the Jersey variety it was also pollinated

with pollens of the Western and San Saba Improved varieties, which had the same maternal parent as the Jersey. Determinations of the weight, volume, and specific gravity were recorded for each nut harvested in 1941. Data were obtained on the same characters in 1942 and 1943, and in addition all light-weight nuts were shelled and the kernels weighed.

Since the degree of dichogamy in most pecan varieties is such that very little pollen of a given variety is shed at the time the stigmas of that variety are receptive, it was necessary to obtain pollens of protogynous varieties for selfing, or for crossing with other protogynous varieties, from trees growing in areas far enough south of the experimental orchard for the blossoming to be at least a week earlier. The pollens of protandrous varieties used in selfing and in crossing with other protandrous varieties were stored and held until the respective varieties were ready to be pollinated.

Some of the various causes of dropping listed by investigators (1, 2, 5, 7) are in no way associated with pollination or lack of pollination, but it is possible that lack of fertilization and certain conditions following fertilization may vary with the kind of pollen used. Hence, in order to determine the period during which differences in the drop of nuts occurred following various controlled pollinations, counts of both the pollinated and the unpollinated bagged nuts were made at intervals during the 1943 season.

Most of the nuts obtained each year from the experimental pollinations were planted and observations were made later on the characteristics of the seedlings.

Effects of Variety of Pollen on Premature Dropping of Nuts

During the period of fertilization drop[1] there were no significant differences in the percentages of nuts that dropped in any of the varieties from pollinations with the different pollens, except that the drop was considerably higher in self-pollinated nuts of the Jersey variety than in those that were cross-pollinated (Fig. 1). The greater drop in the Jersey variety during this period may indicate partial self-incompatibility of pollen and pistil.

During the period of summer drop[2] the percentages of nuts dropping from self-pollinated clusters were significantly greater than those for cross-pollinated clusters in all four varieties (Fig. 1). In Jersey clusters pollinated with pollens of the sib varieties, Western and San Saba Improved, the dropping was intermediate between that of selfed and of cross-pollinated clusters, though the differences were relatively small (Fig. 1). The summer drop of the Mahan and San Saba Improved varieties pollinated with a mixture of equal weights of pollens of these two varieties was intermediate between that of self-pollinated nuts and

[1]The drop occurring from date of pollination to the date of completion of the drop of bagged, unpollinated nuts of a variety is referred to as the fertilization drop.

[2]The drop of nuts from the time all unpollinated nuts drop until the nuts are mature is referred to as the summer drop.

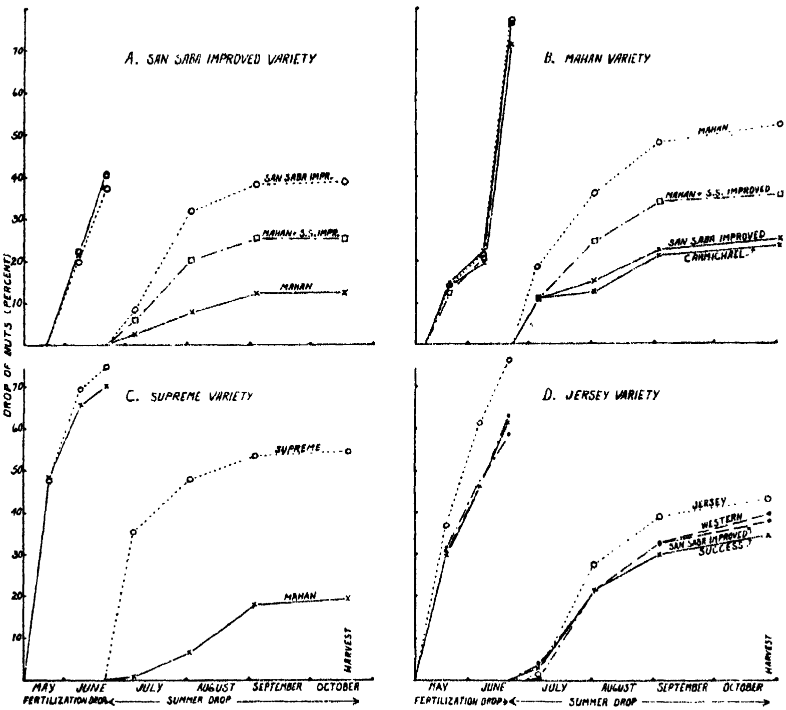

FIG. 1. Premature dropping of pecan nuts from self-pollination, cross-pollination, and pollination with sib varieties of pollen, 1943. The variety of pollen used is indicated for each dropping curve. A—San Saba Improved Variety; B—Mahan Variety; C—Supreme Variety; D—Jersey Variety.

that of cross-pollinated nuts of each variety. Thus, it appears that in each variety approximately equal numbers of egg cells were fertilized by each of the two pollens in the mixture, and that there was little, if any, selectivity or incompatibility of pollen and pistil in any of the four possible combinations.

The percentages of nuts remaining on the trees at harvest varied inversely with the total amount of dropping, and the differences were largely the result of differences in the amounts of summer dropping except in the Jersey variety (Table I).

Based on the number of flowers pollinated, in each variety a greater percentage of nuts remained at harvest in cross-pollinated clusters than in those that were self-pollinated; also a greater percentage of harvested clusters were large (three or more nuts per cluster) in each of the cross-pollinated lots.

The seasonal dropping records indicate that at least a part of the summer drop of pecan nuts may be caused by the after-effects of unfavorable combinations of sperm and egg cells. Though the development of both endosperm and embryo may be initiated, failure of either structure to complete its growth may cause the nut to drop prematurely

TABLE I—NUMBER AND PERCENTAGES OF NUTS HARVESTED FROM SELF-POLLINATED AND CROSS-POLLINATED VARIETIES AND PERCENTAGES OF HARVESTED CLUSTERS CONTAINING THREE OR MORE NUTS (1942 AND 1943)

Variety	Number of Nuts Harvested		Percentage of Nuts Harvested		Number of Nuts Harvested Per Cluster Polli-nated		Percentage of Clusters Har-vested Having Three or More Nuts	
	Selfed	Crossed	Selfed	Crossed	Selfed	Crossed	Selfed	Crossed
			Season of 1942					
Clark	24	88	—*	—*	0.40	0.53	5.5	9.4
San Saba Improved	109	311	—*	—*	1.36	1.73	34.6	53.2
Supreme	110	311	—*	—*	0.69	1.36	5.3	29.9
			Season of 1943					
Jersey	45	95	13.5	28.2	0.42	0.90	14.3	38.1
Mahan	72	261	10.9	19.8	0.49	0.89	11.6	35.3
San Saba Improved	485	371	37.7	51.0	1.07	1.39	19.4	30.4
Supreme	111	116	11.2	24.0	0.39	0.80	3.7	16.7

*Data not recorded.

or the shell may develop without any visible embryo and thus become a pop.[3]

EFFECTS OF VARIETY OF POLLEN ON EMBRYO DEVELOPMENT

In all cases except one, self-pollinations resulted in higher percentages of nuts that contained poorly developed embryos at harvest than did cross-pollinations (Table II). Poor conditions for filling accounted for poor embryo development in some of the nuts of the Mahan and Supreme varieties, but the percentages of poorly developed nuts from self-pollinations were still significantly greater than those from cross-pollinations. The percentages of pops obtained from the same combinations of parent varieties varied considerably in the two seasons, 1942 and 1943. This variation may have been due to differences in conditions favoring premature abscission of nuts, but in all except one instance the percentages of pops harvested were greater from self-pollinations than from cross-pollinations.

In the orchard used for these experiments the Jersey variety previously had produced a relatively high percentage of pops in each of several consecutive seasons. Since it is interplanted with the Western variety and is bounded by trees of the San Saba Improved variety on one side of the orchard, it was thought that pollination by one or both of these sib varieties might have been responsible for the poor kernel development. The data for 1943 show that pollinations by each of these sib varieties resulted in slightly higher percentages of nuts of low specific gravity, and of pops, than did pollen of the unrelated variety, Success.

Since there were differences in the amounts of premature dropping and in the kernel development of nuts from self-pollination, cross-pollination, and pollination with pollen of sib varieties, there were

[3]Mature nuts with no visible embryo are designated as pops.

TABLE II—PERCENTAGES OF POORLY DEVELOPED PECAN NUTS OBTAINED BY SELFING, CROSSING, AND OTHER TYPES OF POLLINATION (1941–1943)

Variety Pollinated	Total Nuts* Examined, Number			Unsalable Nuts (Specific Gravity Below .600), (Per Cent)			Pops,** (Per Cent)		
	Selfed	Crossed	Other	Selfed	Crossed	Other	Selfed	Crossed	Other
				Season of 1941					
Burkett	7	69	—	14.2	5.8	—	—	—	—
Clark	20	55	—	25.0	5.5	—	—	—	—
Mahan	16	21	—	68.7	61.9	—	—	—	—
McCully	6	18	—	50.0	5.6	—	—	—	—
San Saba Improved	43	143	—	16.3	3.5	—	—	—	—
Supreme	20	30	—	50.0	23.3	—	—	—	—
Western	41	277	—	9.8	11.2	—	—	—	—
				Season of 1942					
Clark	21	84	—	47.6	19.0	—	19.0	1.2	—
San Saba Improved	109	309	—	26.6	4.2	—	23.9	1.3	—
Supreme	110	298	—	71.8	62.4	—	20.9	6.0	—
				Season of 1943					
Jersey	45	95	78†	51.1	29.5	30.8†	42.2	25.3	30.8†
Jersey	—	—	72‡	—	—	31.9‡	—	—	27.8‡
Mahan	72	261	Mixed 102††	16.7	6.5	14.7††	2.8	3.1	8.8††
San Saba Improved	485	371	Mixed 230††	26.2	10.5	18.3††	22.7	5.9	14.8††
Supreme	111	116	—	39.6	11.2	—	8.1	2.6	—

*The number of nuts pollinated with each pollen was not the same. All nuts harvested are included in these data except a small number that were weevil infested.
**No record was made of the percentage of pops produced in 1941.
†Sib-pollinated with San Saba Improved.
‡Sib-pollinated with Western.
††Mixed pollen; half by weight Mahan, half San Saba Improved.

corresponding differences in the yields of salable nuts. Data on yields of salable nuts from the varieties used in 1943 are presented in Table III. Selfing reduced the yields of salable nuts of all varieties as compared with cross-pollination but the amount of reduction varied with the variety. The yields of salable nuts of the Mahan and San Saba Improved varieties obtained with mixtures of their pollens were intermediate between those obtained by selfing and by crossing, and the same was true of the yield of the Jersey variety when pollinated by sib varieties, Western and San Saba Improved.

While it is believed that little self-pollination occurs under normal

TABLE III—WEIGHT OF SALABLE NUTS HARVESTED PER FLOWER POLLINATED WITH DIFFERENT VARIETIES OF POLLEN (1943)

Variety	Pollen Used	Weight of Salable Nuts* Harvested Per Flower Pollinated (Grams)	Variety	Pollen Used	Weight of Salable Nuts* Harvested Per Flower Pollinated (Grams)
Mahan	Mahan	0.55	Jersey	Jersey	0.40
Mahan	Mixed**	0.86	Jersey	San Saba Improved	1.02
Mahan	San Saba Improved	1.37	Jersey	Western	0.86
Mahan	Carmichael	1.17	Jersey	Success	1.21
San Saba Improved	San Saba Improved	1.77	Supreme	Supreme	0.30
San Saba Improved	Mixed**	2.34	Supreme	Mahan	0.97
San Saba Improved	Mahan	2.96	—	—	—

*All nuts having a specific gravity of less than .600 were considered unsalable.
**Mahan and San Saba Improved, 50 per cent by weight of each.

conditions in most pecan orchards or groves, which usually contain both protandrous and protogynous varieties, it may occur to an appreciable extent in certain varieties if the trees are isolated, or if pollen of other varieties within pollination range is not shed at the proper time, or if wind movements are unfavorable for distributing available pollen to the receptive stigmas.

Heterosis and Metaxenia Effects of Pollen

The embryo of the pecan constitutes almost the entire kernel, and therefore any differences in the weights of kernels due to different pollens may be attributed to heterosis; likewise, differences in volumes of the nuts may be attributed to metaxenia since the shell tissues are of maternal origin and the size of the nut is determined before the kernel fills the shell. In every case except one, the calculated average weights of kernels of nuts from cross-pollinations were greater than those of similar nuts from self-pollinations (Table IV). Also, the average volumes of cross-pollinated nuts were greater than those of selfed nuts in all cases but three. The data for the pops were omitted from the above calculations since they are probably not comparable with those for nuts with embryos insofar as the effects of heterosis and metaxenia are concerned.

Space does not permit presentation of statistical data but the results of a statistical analysis may be summed up as follows: Considering the combined data for 1942 and 1943, the nuts resulting from cross-pollinations were significantly larger in volume and contained heavier kernels than those from self-pollinations, notwithstanding the facts that all the pops were omitted from the calculations, and that a greater percentage of the nuts dropped from self-pollinated clusters, thus decreasing the competition for nutrient materials for the remaining nuts as compared with those in the cross-pollinated clusters. As a whole the nuts with visible embryos were significantly larger and less variable in volume than the pops from the same pollinations, thus indicating that a shell containing a developing embryo usually grows larger than a similar shell in which no visible embryo is present. Within clusters of the same size in the Supreme variety the variability in the volumes and in the weights was significantly greater for nuts from self-pollinations than for those from cross-pollinations, but in nuts of the San Saba Improved variety the variability was slightly less for the selfed nuts. Due to insufficient numbers the variability of nuts of the other varieties was not calculated.

The above analyses show significantly greater heterosis and metaxenia effects in cross-pollinated nuts than in those that were self-pollinated. On the average, self-pollination causes a decrease in the number of heterozygous pairs of alleles in the progeny by one-half, while the crossing of different strains usually results in an increase; therefore, it is evident that the heterosis effects on the weights of the kernels and the metaxenia effects on the volumes of the nuts were both associated with an increase in the degree of heterozygosis in the embryo, and that the variability in the weights of kernels and in the volumes of comparable nuts depends upon the genetic constitution of the parents.

TABLE IV—The Averages of Number of Nuts Harvested per Cluster and of Weight, Volume, Specific Gravity, and Kernel Weight per Nut for Seven Varieties of Pecan Pollinated with Different Varieties of Pollen (1942 and 1943)

Variety of Pollen Used	Average Number of Nuts Harvested Per Cluster*	Average Weight Per Nut** (Grams)	Average Volume Per Nut** (CC)	Average Specific Gravity**	Calculated Average Weight of Kernel Per Nut**† (Grams)
	Clark Variety—Season of 1942				
Clark	1.41	4.83	7.67	0.629	2.30
Carmichael	1.58	6.03	9.04	0.667	3.05
Curtis	1.10	5.66	8.42	0.673	2.89
Odom	1.57	5.80	8.64	0.671	2.95
	San Saba Improved Variety—Season of 1942				
San Saba Improved	2,10	5.10	6.93	0.736	2.88
Carmichael	2.40	5.25	6.98	0.751	3.01
Evers	3.00	5.21	7.17	0.726	2.91
Odom	2.73	5.26	7.35	0.716	2.91
Oklahoma	2.11	5.11	7.08	0.722	2.84
Russell	2.29	5.52	7.29	0.757	3.19
	Supreme Variety—Season of 1942				
Supreme	1.47	3.06	5.36	0.572	1.40
Odom	2.06	3.30	5.64	0.585	1.55
Mahan	1.93	3.32	5.71	0.581	1.55
	Jersey Variety—Season of 1943				
Jersey	1.60	5.68	7.57	0.751	3.30
San Saba Improved	1.95	5.76	7.03	0.820	3.55
Western	1.76	5.51	6.99	0.788	3.31
Success	2.26	5.98	7.60	0.786	3.58
	Mahan Variety—Season of 1943				
Mahan	1.67	5.64	7.78	0.726	3.08
Mixed‡	1.98	6.39	8.50	0.752	3.59
San Saba Improved	2.18	6.79	8.88	0.764	3.86
Carmichael	2.20	6.78	8.90	0.762	3.84
	San Saba Improved Variety—Season of 1943				
San Saba Improved	1.75	6.26	7.81	0.801	3.76
Mixed‡	1.78	6.36	7.96	0.799	3.81
Mahan	2.02	6.37	7.78	0.818	3.87
	Supreme Variety—Season of 1943				
Supreme	1.35	3.70	5.50	0.674	2.00
Mahan	1.61	4.35	5.73	0.758	2.57

*Includes pops.
**Does not include pops.
†The fraction of the specific gravity of the nuts attributed to the shell was as follows: Clark .330, Jersey .315, Mahan .330, San Saba Improved .320, Supreme .310.
††Mahan and San Saba Improved, 50 per cent by weight of each.

Pollen from a variety that itself produces large nuts does not necessarily stimulate the embryo and the shell to greater development than does pollen from a variety that normally produces small nuts. The nuts of the Mahan variety normally are much larger and contain heavier kernels than those of the San Saba Improved and Carmichael varieties, but selfed Mahan nuts were considerably smaller in size and had lighter kernels than those produced by crossing with the latter varieties.

Pollens of various varieties with relatively different ripening dates failed to exert any apparent metaxenia effects on the ripening date of nuts of the San Saba Improved variety in 1942.

Association of Seedling Vigor with Size and Filling of the Nuts

There was considerable variation in the vigor of the seedlings grown from the nuts produced in these studies but as a whole those of self-pollinated nuts made 23 per cent less growth in height than did those of comparable cross-pollinated nuts. The shoots emanating from buds of inbred seedlings propagated to other trees also were less vigorous than either those from comparable buds of cross-bred seedlings or those from the innate buds of the topworked trees. These facts indicate that growth in the pecan is stimulated by heterozygosis and that vigor declines as the heterozygous condition is decreased by inbreeding, and that the majority of seedling trees produced under natural conditions probably are of cross-bred origin. This probability is further strengthened by evidence that relatively little self-pollination occurs under natural conditions.

Since the genetic constitution of the germ plasm that results from the union of the two reproductive cells is directly associated with the vigor of the pecan seedling, the heterosis effects of the pollen on the development of the kernel, and the metaxenia effects of the pollen on the volume of the nut, it follows that in strictly comparable nuts any differences in volume or kernel development should indicate differences in embryo vigor. While the data show that these correlations exist, they are small, and because of the difficulty of ascertaining whether nuts were equally favored during their development on the tree, it appears unlikely that the vigor of seedlings can be foretold with any reasonable degree of accuracy from the nut characteristics, except possibly in extreme cases.

Summary

1. There was no statistically significant evidence of incompatibility of pollen and pistil in self-pollinated or cross-pollinated nuts of the four varieties used in 1943, thus confirming the results of preliminary experiments with several other varieties.

2. There was no apparent selectivity of pollen in fertilization of the egg cells in the Mahan and San Saba Improved varieties after pollination with a mixture of the pollens of the two varieties.

3. In the four varieties studied, self-pollination was followed by a much greater summer drop of immature nuts than was cross-pollination.

4. Based on the number of flowers pollinated, the precentages of nuts harvested were much greater in cross-pollinated clusters than in those that were self-pollinated; also a higher percentage of the clusters were large (three or more nuts).

5. In every case but one, the percentages of poorly developed nuts (specific gravity below .600) harvested were much greater in self-pollinated lots than in those that were cross-pollinated. Conversely, the relative yields of salable nuts were greater in cross-pollinated lots.

6. Pollination of the Jersey variety with pollens of sib varieties produced the same effects as selfing, but to a lesser extent.

7. There were significant heterosis and metaxenia effects of pollen

on the weight of the pecan kernel and on the volume of the nut, respectively, which were associated with the degree of heterozygosis in the embryo.

8. The evidence presented indicates that the genetic constitution of the pecan plant normally is highly heterozygous, and that the vigor of the plant is decreased by inbreeding.

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A Study of the Degree of Filling of Pecan Nuts as Affected by the Number Produced by the Tree

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FERTILIZER treatment, soil moisture, leaf area, and size of crop are enumerated by Finch and Van Horn (5) as factors suggested by research workers as affecting the degree of development of pecan kernels. This paper presents the relationship that was found to exist between the size of the crop (number of nuts) produced by a tree and the degree of filling of the kernels.

Materials

This study was conducted in 1944 on 14-year-old pecan trees *(Carya illinoensis* Wang, K. Koch) of the Schley, Moore, Dependable, Sabine, Teche, Mahan, and Caspiana varieties. These trees had all been given summer cultivation with a winter legume cover crop since they had been planted, and were large, vigorous trees for their age.

The 35 Schley trees used were growing on Miller clay soil and produced a heavy pistillate bloom in the spring of 1944. These trees were all given two prepollination applications of 4–1–100 bordeaux and two summer applications of 6–2–100 bordeaux. These trees were a part of an experiment in which different degrees of severity of pruning had been practiced. The heavily pruned trees made considerable second growth during June while the lightly pruned and the unpruned trees made little and no second growth, respectively. In early October scorching of the leaflets followed by abscission of the leaves that were formed during the spring growth, occurred on all Schley trees. The leaves formed during the summer growth period did not scorch or abscise until killed by frost in December. This difference in the amount of summer growth resulted in correlated differences in the amount of healthy foliage on the trees during October and November, the most foliage being on the heavily pruned trees because of their having made the greatest amount of summer growth.

Eighteen Moore trees growing on Miller clay soil were given two 4–1–100 bordeaux sprayings to diminish the setting of the pistillate flowers (3); 17 adjoining Moore trees were not sprayed. Two Moore trees growing on a Miller loam soil were given two 4–1–100 bordeaux sprayings to diminish the setting of the pistillate flowers; four adjoining Moore trees were not sprayed. All of these Moore trees had pistillate clusters on nearly all of the 1944 shoots. Due both to the effectiveness of the set-control practices used and to differences in pollination, variations existed between the trees in the amount of nuts set. Based on a count of only the spring-growth leaves the leaf-to-nut ratio varied from 2½ to 1 on some trees to 8 to 1 on other trees. The Moore trees on the clay soil made considerable second growth in June. Very little second growth was made by the Moore trees on the loam soil. The late September and early October scorching and later abscis-

ing of the leaflets that had been formed during the spring growth occurred on the trees that had not been sprayed with bordeaux. This condition occurred first on the unsprayed trees on the clay soil and later on the unsprayed trees on the loam soil. Defoliation of the bordeaux-sprayed trees occurred 6 weeks later than it did on the unsprayed trees on the same soil type. No defoliation of the second growth occurred until December.

Six Sabine, five Teche, six Mahan, and six Dependable trees on Miller loam soil were used in this study. Some of these trees were sprayed with bordeaux 4–1–100 to lessen the setting of the pistillate flowers, but this did not reduce the set sufficiently to get the desired amount of leaf area per nut. The nuts on two trees of each of these varieties were thinned in order to have some trees in this study having a leaf-to-nut ratio as high as has been shown by Sitton (6) and Crane (1) to be necessary for the production of well-filled nuts. This thinning work was done in July by pulling off a sufficient number of the largest nut clusters to reduce the quantity of nuts on the tree to the desired leaf-to-nut ratio, using bamboo poles having a heavy wire hook on the end.

Mahan and Teche thinned trees had a leaf-to-nut ratio of 6 to 1, and Dependable and Sabine thinned trees had a leaf-to-nut ratio of 8 to 1. The unthinned trees had leaf-to-nut ratios of one-half to two-thirds that of the thinned trees. Leaf scorch and abscising of the leaflets did not occur on any of these trees to any extent until late in October, and was a little more severe on the unsprayed trees than it was on those sprayed with bordeaux in April.

Four Caspiana trees growing on Miller loam soil were used in this study. Two of these trees were sprayed in April with 4–1–100 bordeaux to diminish the setting of the pistillate flowers, and only a moderate crop was set by them. The unsprayed trees, however, set heavy crops. Leaf scorch occurred in late October on the Caspiana trees but was not severe on the unsprayed trees and was only mild on the sprayed trees.

The nuts were harvested from the trees in this experiment in November and December. A record was made of the weight of the nuts harvested from each tree, and samples of 1½ pounds of nuts were taken for determination of the degree of filling and size of nut by methods already outlined (2). Two samples were taken from each Schley and Moore tree, and four samples were taken from each tree of the other varieties. From the data so obtained the number of nuts produced by each tree was calculated.

In the early spring of 1945, before the beginning of growth, the trunk circumference of each tree was measured and the cross-sectional area of each tree trunk in square inches was calculated. The number of nuts produced per square inch of cross-sectional area of each tree trunk was calculated by dividing the total number of nuts produced by that tree by the number of square inches in the cross-sectional area. Using the method of least squares, the linear relationship of the number of nuts produced per square inch of cross-sectional area of tree trunk (X) to the percentage of well-filled nuts produced by the trees (Y) was obtained. These data are presented graphically in Figs. 1 and 2.

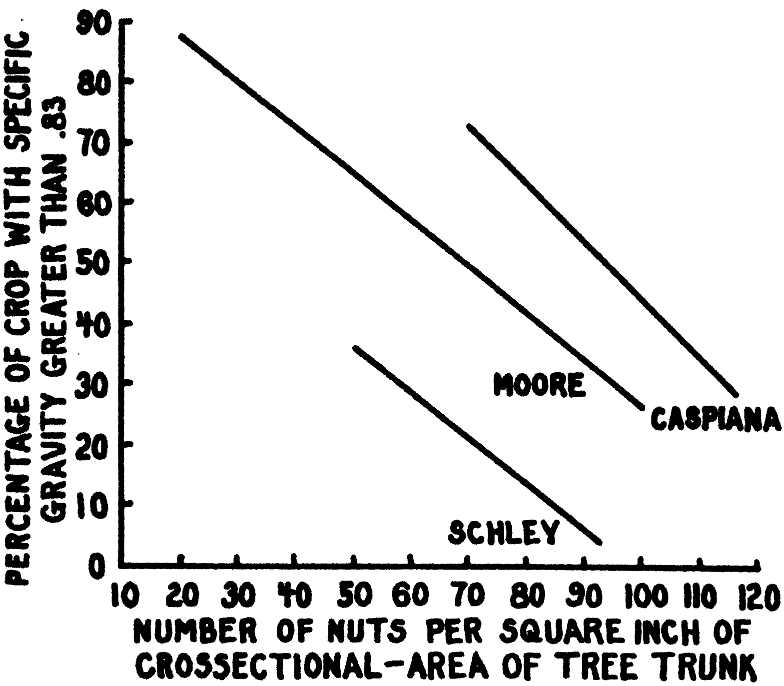

FIG. 1. The percentage of the crop having a specific gravity of more than .83 in relation to the number of nuts produced per square inch of cross-sectional area of tree trunk.

Determinations of the statistical constants were made according to the methods given by Ezekiel (4) and are presented in Table I.

It will be noted in Fig. 1 that a specific gravity of .83 or higher was used as representing well-filled nuts of Caspiana, Moore, and Schley varieties; and in Fig. 2 a specific gravity of .70 or higher was used as representing well-filled nuts of Teche, Sabine, Mahan, and Dependable varieties. These are arbitrary specific gravity limits, and are in no way to be taken as showing that well-filled nuts of any variety have a specific gravity different from that of another variety. In this study it was necessary to use these two specific gravity classes because of the

TABLE I—RELATION OF THE NUMBER OF NUTS PRODUCED PER SQUARE INCH OF CROSS-SECTIONAL AREA OF TREE TRUNK (X) TO THE PERCENTAGE OF WELL-FILLED NUTS PRODUCED BY THE TREES IN 1944

Variety	Specific Gravity	bx.y	rx.y	dx.y (Coefficient of Determination)	Sx.y (Standard Error of Estimate)
Sabine	.70 up	−0.7425	.936	.88	5.0
Teche	.70 up	−0.8596	.925	.85	7.8
Dependable	.70 up	−1.0842	.795	.63	6.3
Mahan	.70 up	−0.9905	.779	.61	9.2
Moore	.83 up	−1.0954	.865	.75	10.3
Schley	.83 up	−0.7372	.575	.33	12.8
Caspiana	.83 up	−0.8993	.867	.75	16.5

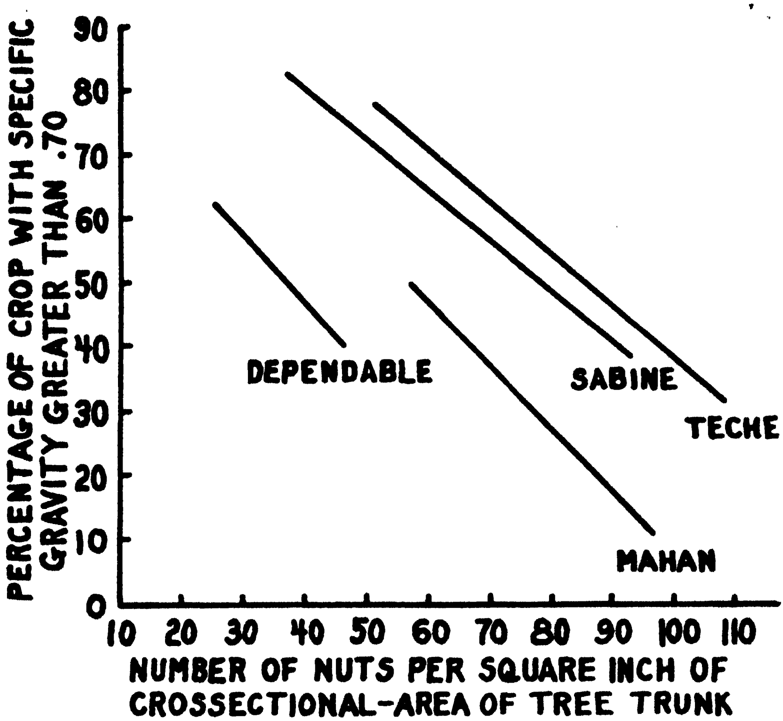

FIG. 2. The percentage of the crop having a specific gravity of more than .70 in the relation to the number of nuts produced per square inch of cross-sectional area of tree trunk.

differences in degree of filling of the several varieties. The present crops of those varieties for which a specific gravity of .70 was used had few if any nuts with a specific gravity of .83 or higher. In contrast, the Caspiana, Moore, and Schley varieties had very few nuts with a specific gravity of less than .70; consequently, if that specific gravity had been used for these varieties no differences would have been found between the degree of kernel development of trees having a heavy nut crop and those with a light nut crop.

It would have been best in this study to have used the same specific gravity for all varieties, and perhaps a specific gravity of .75 or somewhat higher could have been used satisfactorily for all the varieties as representing well-filled nuts. However, the nut samples had been separated into specific gravity classes of below .60, .60 to .69, .70 to .82 and .83 up; and it was not possible to reseparate them. In this study the percentage of well-filled nuts produced by a tree means the percentage of the total crop by weight that had a specific gravity of .70 or higher in the case of Teche, Sabine, Mahan, and Dependable; and the percentage of the nut crop by weight that had a specific gravity of .83 or higher in the case of Caspiana, Moore, and Schley varieties.

Results

Data presented graphically in Figs. 1 and 2 show that the percentage of well-filled nuts produced decreased as the number of nuts produced by the tree increased. The statistical constants (*b*) presented in Table I show how much decrease occurred in the percentage of well-filled nuts harvested for each increase of one nut per square inch of cross-sectional area of tree trunk. This constant was the smallest for Schley and Sabine and largest for Moore and Dependable. In general, it appears that under the conditions of the experiment the percentage of well-filled nuts produced by a tree decreased 0.75 per cent to a little more than 1 per cent with each increase of one nut per square inch of cross-sectional area of the tree trunk.

The coefficient of linear correlation (*r*) is quite high for all varieties except Schley. According to Ezekiel (4) the coefficient of determination (*d*) shows the proportion of the variance in the dependent factor that is associated with the independent factor. The difference between (*d*) and unity represents the amount of variance not associated with the variables studied. With the exception of Schley, these data show that more of the variance in the percentage of well-filled nuts was correlated with variation in the number of nuts produced per square inch of cross-sectional area of the tree trunk than was associated with all the various factors not included in the study. With Sabine, Teche, Caspiana, and Moore, 75 per cent or more of the variance in the percentage of well-filled nuts was correlated with the number of nuts produced; accordingly, 25 per cent or less of the variance was correlated with other factors.

Discussion

It is generally recognized that the leaves of a pecan tree synthesize all or nearly all of the primary carbohydrate material out of which the more complex carbohydrates and proteins are formed. Since these carbohydrates and proteins are used in the production of leaves and wood, as well as fruit, it is reasonable to expect that the amount of such material available for use could sometimes be insufficient for best growth and fruiting. Finch and Van Horn (5) have shown that this condition will occur with pecans. The method of expressing the number of nuts on a pecan tree in relation to the leaf area of the tree has been used by Sitton (6) and by Crane (1) to show how, within limits, the degree of development of the kernel of the nut increases with increased leaf area per nut. In final analysis this is a method of expressing the amount of an essential material available to a pecan nut for the growth and development of its kernel. It has been shown by Finch and Van Horn (5), however, that the environment of the pecan tree will affect the growth of the tree; and that this in turn will affect the amount of carbohydrate and protein material available for use in the development of the kernel of the nut.

It is apparent, then, that since the leaf-to-nut ratio is only a relative measure of the potential amount of the material available per nut and since the amount of the materials per leaf will vary because of the environmental conditions, it is reasonable to expect that the degree

of kernel development of the nut will not be the same for all conditions even though the leaf area per nut is the same. The kernel development of the pecan nuts, then, becomes essentially a dual problem of the production and the utilization of plant food.

The regression coefficient (*b*) for the several varieties given in Table I shows considerable variance in the ability of the different varieties to produce well-filled pecans. Of the varieties listed, Caspiana and Schley usually produce the best-filled pecans; and Mahan and Dependable usually produce nuts with the poorest kernel development. It will be noted in Table I that the (*b*) coefficient for Schley and Caspiana is smaller than for Mahan and Dependable. Some of this difference could be associated with the size of the nuts produced by the respective varieties. Mahan and Dependable are large nuts and require more material to produce the large kernel that is necessary to properly fill them than is needed for Schley and Caspiana which are smaller nuts having smaller kernels. However, in Table I, Moore which is a small nut has a high coefficient while Sabine which is a large nut has a small coefficient. This apparent discrepancy can be explained by the fact that Moore foliage scorched early while Sabine maintained healthy foliage.

A growing season and cultural program conducive to the maximum synthesis of plant food coupled with the minimum utilization of it in the growth of any part of the tree other than the nuts should be expected to produce the largest quantity of nuts having well-developed kernels. Data presented by Sitton (6) showed that well-filled Schley nuts were produced with as few as four leaves per nut. The data presented by Crane (1) showed that under different conditions six to eight leaves were necessary per nut for proper kernel development. Data presented here indicate that probably 10 or more leaves per nut would be necessary for proper kernel development of most varieties studied. The lack of agreement shown by these workers can probably be explained by differences in the efficiency of the leaf area of the trees used by the different workers. The fact that early scorching of the leaves occurred on most of the trees used in this study shows that they did not function at maximum efficiency, and this condition probably existed long before the scorch was apparent. That this condition can be expected to occur frequently is shown by unpublished data taken at the U. S. Pecan Field Station at Robson, Louisiana, from 1937 to 1944 inclusive. Furthermore, these data show that leaf scorch and early defoliation of the trees occurred much earlier and was more severe in years having excessive and frequent rainfall during the time the spring growth of the trees was being made than it did in years when rainfall was light during that period. Rainfall during the period of leaf growth in 1944 was both frequent and heavy. Under these conditions it can also be expected that it will be necessary to have a greater leaf area per nut, or fewer nuts per square inch of cross-sectional area of the trunk, for best kernel development than would be the case if rainfall had been light during that period.

Spraying the foliage with bordeaux mixture during this period of leaf growth delays the leaf scorching and defoliation by about six weeks and increases the number of nuts that can be properly filled.

Use of the information presented here as well as that of Sitton (6) and Crane (1), and knowledge of the environmental conditions under which the spring growth of the foliage was made, should make it possible to know how many nuts a tree would be capable of properly filling. Having determined this, the trees could be sprayed with bordeaux mixture to increase the efficiency of the foliage, or else the amount of the crop on the trees could be reduced either by hand thinning or by using a set-reducing spray. The use of bordeaux mixture at the proper time would serve two purposes in that the setting of the nuts could be reduced (3) and also the bordeaux would be effective in increasing the efficiency of the leaf area. The proper time for making this application of bordeaux mixture has not been definitely determined. The indications are that to be most effective in reducing the setting of the nuts the bordeaux should be applied just before or at the time of first stigma receptivity.

It is apparent from this study that there was an insufficient number of leaves per nut on most trees to properly fill the nuts and permit sufficient plant food to remain in the tree to produce pistillate flowers the following year. No Mahan or Schley trees produced any pistillate or staminate flowers in 1945, showing that under the growth conditions of 1944 it is necessary to have probably as many as 10 leaves per nut if well-filled nut crops are to be produced annually. The Teche, Dependable, Sabine, Caspiana, and Moore trees that produced pistillate flowers in 1945 were the ones that had the fewest nuts per square inch of cross-sectional area of the trunk the previous year.

The beneficial effect of the bordeaux spray in increasing the efficiency of the foliage is shown by the Moore trees. No Moore tree produced more than 2 per cent of a full pistillate bloom in 1945 unless it had been sprayed with bordeaux the previous year. Sprayed Moore trees produced 14 per cent more nuts with a specific gravity greater than .83 in 1944 than did adjoining unsprayed trees having the same number of nuts per square inch of cross-sectional area of the tree trunk. This difference was not statistically significant, but does indicate the necessity of having a greater leaf area per nut if that leaf area is unhealthy than is required when the leaves are healthy. However, bordeaux-sprayed trees that had too heavy a nut crop in 1944 failed to produce any pistillate flowers in 1945.

The high coefficients of determination found show that for a given variety and for a given season or foliage condition, the number of nuts on the tree is the most important factor in the production of well-filled nuts. If this study should be conducted for several years, however, it would be expected that, because of the wide differences in the amount of scorch between years, the resulting variance would greatly reduce this coefficient.

Conclusion

Data are presented here to show that the percentage of well-filled pecan nuts decreased as the number of nuts on the tree increased. It is suggested that more leaves are required per nut to properly develop the kernel in some years than are required in other years.

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Experiments with Growth Substances on Pecans

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Many pecan nuts are lost annually by shedding due to some factors other than damage caused by insects and diseases. Certain varieties of pecans shed a higher percentage of the nuts than others and with such varieties production is often seriously reduced during years of heavy drop.

In 1941 experiments were initiated to determine whether any of the growth promoting substances such as those used by Gardner and others on apples would be effective in preventing the shedding of pecan nuts. The chemicals tested during the period of investigation were napthaleneacetic acid, napthaleneacetamide, indoleacetic acid, indolebutyric acid, and one commercial product containing Napthaleneacetic acid. The concentrations of each were .01, .001, and .0001 per cent, except the proprietary compound which was used as recommended for apples. In the experiments on nut shedding, branches carrying predetermined numbers of nuts were sprayed with the chemicals on different dates from May to August. Curtis, Kennedy, Success, Frotscher, and Zink varieties were included in the experiments.

Two types of experiments were conducted to test the effects of growth substances on root growth of pecans. In one case Stuart nuts were soaked in the various concentrations then germinated, and the root growth evaluated. The other tests were carried out with nursery stock. Roots of the trees were immersed for 24 hours in solutions of the different dilutions. In these tests the concentrations were the same for all chemicals as those used in the nut shedding experiments and in addition one commercial preparation containing indolebutyric acid.

The tests to study the effects of the different chemicals on nut shedding were conducted from 1941 to 1944. Shedding was not very heavy in 1941, but it was rather severe in the other years. Not one of the treatments was effective in reducing nut dropping. In some years with one or more varieties the results would be in favor of the treatments, while other years the reverse would be true. There was nothing consistent in the results except in this variability. C. L. Smith (1) reported no beneficial effects of certain chemicals in preventing pecan nut shedding.

Seedlings grown from nuts treated by soaking in napthaleneacetic acid or indolebutyric acid produced stronger root systems than did other treatments. The .0001 per cent concentration of both chemicals was somewhat better than the others. The differences in root growth were exhibited in all replications, yet it is doubtful if they were great enough to justify large scale treatments of nuts for planting in commercial nursery operations.

Nursery trees transplanted after treatment by immersing the roots in the growth substances responded best to indolebutyric acid and second to napthaleneacetamide. The .01 per cent concentration gave better results than the others used. The commercial preparation containing indolebutyric acid gave as good results as did the chemical diluted in the laboratory.

Increased root growth in pecan trees will be obtained when the roots are treated with indolebutyric acid and other suitable chemicals under conditions similar to those of the experiments reported. This would seem to be a worthwhile treatment, especially for large trees being planted in the home grounds. However, the results obtained might not justify the expense of materials and labor involved in making the treatments, when commercial orchard plantings are being made. Romberg, Gossard and others have previously reported on the effects of growth substances on pecan roots

The growth-promoting chemicals tried were not effective in preventing the shedding of pecan nuts treated. In many of the experiments, frequently there were as many and sometimes more nuts shed from the treated branches as there were from the checks. This was true in all replications.

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Boron Uptake in Pecans

By G. H. BLACKMON and H. W. WINSOR, *University of Florida, Gainesville, Fla.*

IT has been previously shown that boron is necessary in the nutrition of pecans grown in sand and water cultures and that there was a greater utilization of nitrogen by the seedlings with boron applied than when omitted. However, so far as is known, no reports have been made on experiments to determine the effects of boron on pecans in the orchard.

Many of the soils in Florida show a relatively low boron content, and it was decided to determine if boron would be of value in pecan fertilization. Consequently, in the spring of 1945, this study was begun in a small orchard of Stuart pecans set in 1928 on Arredondo loamy fine sand on the Florida Agricultural Experiment Station farm at Gainesville. This paper is a report of the results during the first year. The Arredondo soil series is one of the heavier and more fertile in the northwest quarter of the Florida peninsula. The surface soils vary from gray to grayish-brown and the subsoils from yellow to yellowish-brown. Considerable variation in physical and chemical composition is often encountered within a rather limited area. The reaction (pH) ranges from slightly acid in the surface soil to strongly acid in the lower subsoil. These soils support a native cover consisting largely of hardwoods, with sweet gum and hickory predominating.

The trees were divided into four blocks (A, B, C, D) of seven trees each, and each block divided into seven single tree plots. Treatments in each block were randomized, thus there were four replications. Borax was used as the source of boron, being applied on June 7, 1945, in the following amounts: 0, ½, 1, 2, 4, 8 and 16 pounds per tree. Nitrogen, phosphoric acid and potash fertilizers had been previously applied in like amounts in all replications. The soil was very dry at the time the borax was applied and remained so until June 18, when the summer rains began. In Block B soil samples were taken from eight locations about each tree under the branch spread prior to the borax applications and on five dates thereafter, and the water-soluble boron determined. Leaf samples also were taken from these trees (Block B) at the time the borax was applied and on nine dates thereafter, and the boron determined. On nine dates the trees in all replications were examined and the boron toxicity in the leaves scored as to the percentage of leaves showing marginal burn.

The data on the boron content of the soil in which the experimental trees are growing are presented in Table I, along with those for the leaves. It will be noted that the native water-soluble boron in the 0–7-inch zone ranged from 0.09 to 0.18 ppm for the different tree locations.

The boron in the leaves at the time borax was applied varied from 0.39 to 0.60 micrograms per 10 square centimeter of leaf. The data in Table I show that the boron content in the leaves on all trees increased during the sampling period. In the check tree the highest amount was recorded on October 2, which was the last date leaves were collected.

TABLE I—Boron Content of Pecan Foliage as Related to Amount of Borax Applied to the Soil. 1945

Tree No.	Borax Per Tree (Pounds Jun 7, 1945)	Water-Soluble Boron in Soil Ppm 0–7 inches, Apr 20, 1945	Micrograms Boron Per 10 Sq Cm of Foliage on Dates Stated									
			Jun 8	Jun 21	Jun 26	Jul 2	Jul 9	Jul 18	Jul 26	Aug 16	Sep 10	Oct 2
11	0	0.14	0.60	0.86	1.10	1.16	1.64	1.98	2.30	2.18	2.66	2.90
12	½	0.12	0.57	0.92	1.16	1.92	2.48	3.66	4.66	4.50	3.80	4.26
10	1	0.14	0.50	0.84	1.56	2.58	3.46	7.00	9.50	14.26	6.12	7.12
8	2	0.18	0.44	0.76	1.64	2.66	6.40	11.26	8.12	14.00	7.62	8.12
13	4	0.09	0.47	0.94	2.08	5.24	8.80	14.26	21.50*	25.50	13.50	14.76
6	8	0.14	0.39	0.78	2.32	5.40	11.38	18.12*	23.50	27.50	14.76	15.88
9	16	0.11	0.43	0.98	3.08	10.68	17.76*	29.76	37.26	37.50	22.50	20.00

*Marginal leaf burn first observed in samples for analysis.

For those trees receiving borax the amount of boron in the leaves increased until August 16, followed by a distinct decrease. The borax applied evidently went into solution and was largely leached out of the soil, which is substantiated by the decreased amounts found in the soil on the later sampling dates.

It is of interest to note that none of the trees completely defoliated prematurely. Those with applications of 8 and 16 pounds showed 100 per cent marginal leaf burn, yet held most of their leaves until time for normal defoliation. This would seem to account for the fact that there was not a great amount of late summer growth in severely affected trees, but the growth that did appear late was examined and the percentage of the young leaves showing marginal burn is presented in Table II.

The degree of boron toxicity in the leaves was recorded on nine dates after borax was applied. The data in Table II show that ½- and 1-pound applications did not produce toxicity and 2-pound applications only 5 per cent in two trees and none in the other trees. The four trees which received 4 pounds of borax showed traces of toxicity in 1 month which, by September 7, had increased to 5, 20, 25, and 100 per cent, while those with 8-pound applications reached 20, 25, 65,

TABLE II—Marginal Burn on Pecan Foliage as Related to Borax Applications to the Soil

Date	Borax Applied Per Tree, June 7, 1946 (Pounds)						
	0	½	1	2	4	8	16
	Per Cent of Leaves Showing Marginal Burn—Average of Four Replications						
Jul 9	0	0	0	S	T	T	S
Jul 11	0	0	0	S	T	T	7
Jul 16	0	0	0	T	T	S	15
Jul 20	0	0	0	0	S	S	38
Aug 1	0	0	0	0	15	13	80
Aug 9	0	0	0	S	32	30	95
Aug 23	0	0	0	S	36	44	100
Sep 7	0	0	0	S	38	53	100*
Sep 29**	0	0	0	0	0	0	88

*Leaves on new growth showed 10 per cent in one tree on this date.
**Only leaves on new growth were scored on this date.
T = Trace of toxicity symptoms.
S = Slight amount of toxicity symptoms.

and 100 per cent on the same date. The 16 pounds of borax produced toxicity rather early, and all four trees were given a 100 per cent toxicity score either on August 9 or August 23. When toxicity symptoms were observed in the samples analyzed, the extractable boron in the leaves was found to be from 17 to 21 micrograms for 10 square centimeter. Therefore, it would seem that 10 to 12 micrograms per 10 square centimeter of leaf might be the safe upper limit of boron concentration, assuming that other detrimental effects do not precede the actual necrosis.

Soil values for boron in all treatments were determined for the 0–14-inch zone, because of rapid penetration to that depth. Averages of these data, along with those for the leaves, are presented in Table III. It will be noted that the soils for the check increased slightly in soluble boron during the period of heavy rainfall, but showed a reduced amount in dry periods of spring and fall. The average value for the soil under the treated trees was the same as that for the check in the beginning, but increased greatly after borax was applied. With heavy rains there was evidently considerable leaching and the soil lost much of the soluble boron, but on October 22 it was still nearly 12 times more than in the untreated soil. The leaves in the check increased in boron content until the last sampling date of October 2, when the foliage had declined sufficiently that it did not seem advisable to make later collections. The averages for the leaves from the borax treated trees follow somewhat the same trend as those for the soil.

TABLE III—RELATIONSHIP BETWEEN WATER-SOLUBLE BORON IN ARREDONDO LOAMY FINE SAND AND THE BORON UPTAKE BY 17-YEAR-OLD STUART PECANS (SOIL VALUES REPORTED AS PPM. B IN AIR-DRY SOIL, SAMPLED 0–14 INCHES DEEP; PLANT VALUES AS MICROGRAMS OF EASILY EXTRACTABLE B PER 10 SQ. CM. OF FOLIAGE)

Soil	Borax, Soil Application (Pounds Per Tree)	Inches of Rainfall Since Borax Applied (June 7)**					
			4.94	12.78	27.02	33.76	34.51
		Soil Boron (Ppm)					
		Apr 20	Jun 26	Jul 20	Aug 21	Sep 18	Oct 22
Values for check tree...	0.00	0.09	0.11	0.11	0.10	0.11	0.08
Treated trees, average..	5.25	0.09	4.61	5.62	1.66	1.70	0.94
Plant		Foliage Boron (Micrograms)					
		Jun 8	Jul 9	Aug 16	Sep 10	Oct 2	*
Values for check tree...	0.00	0.60	1.64	2.18	2.66	2.90	*
Treated trees, average..	5.25	0.47	8.38	20.55	11.38	13.19	*

*After Oct. 2 natural foliage decline was sufficiently rapid that sampling at a later period was not deemed advisable.

**For 20 days previous to June 8, when first foliage samples were obtained, rainfall was only 0.35 inch, 0.23 being recorded on May 28. The limited boron uptake is reflected in foliage analysis of June 8.

The foliage analyses were done by an extraction method, the full details of which are to be published by the junior author. Aside from

its advantages of greater rapidity and sensitivity this procedure precludes possible contamination and loss which may be encountered in methods employing ashing and filtration. The 5 square centimeters for analysis consisted of eight strips 2.5 x 25.0 mm, one strip from each of eight leaflets taken at eight equidistant points around the tree. These leaflets were taken from near the tip of (excluding terminal) leaves cut from uniform positions on the twigs. These foliage strips were extracted in a Coors size 00 porcelain dish, and after the strips were removed the extracted boron was determined by the turmeric micromethod modified from the original procedure of Naftel. Values down to 0.1 microgram B per determination can be precisely evaluated. Of the total boron present an average of 42.76 per cent was extracted by this method, and the degree of extraction appears acceptably uniform, even over the wide ranges of boron encountered in this experiment. Analyses were reported on the basis of 10 square centimeter of foliage as a convenient metric unit. The average dry weight of 10 square centimeters of foliage was 0.0749 grams, so the extractable B per 10 square centimeters can be converted, if desired, to total B as parts-per-million on the dry-weight basis. The factor for conversion is calculated from the following equation:

$$\frac{1.0000 \text{ (gm.)}}{\text{Wt. of 10 sq. cm.}} \times \frac{\text{Total B } (\%)}{\text{B extracted } (\%)}$$

$$\text{By substitution: } \frac{1.0000}{0.0749} \times \frac{100.00}{42.76} \; 31.22$$

By use of this factor the lowest value reported for tree 9 (0.43 microgram per 10 square centimeters) becomes 13.42 ppm, and the highest value (37.50 micrograms per 10 square centimeters) becomes 1170.75 ppm. As these two foliage samples were taken on June 8 and August 16, respectively, they represent a boron gain of 8623 per cent within 10 weeks' time.

Factors Affecting Growth of Newly Transplanted Tung Trees During Dry Weather

By Marshall S. Neff, *U. S. Department of Agriculture, Cairo, Ga.* and George F. Potter, *U. S. Department of Agriculture, Bogalusa, La.*

In southern Georgia and western Florida the total annual precipitation is in the neighborhood of 50 inches, but it is not evenly distributed and droughts frequently occur both in spring and fall. The spring droughts often render it difficult to get satisfactory growth of newly transplanted tung trees. That has been true in each of the last three seasons, 1943, 1944, and 1945. If the growth is checked in spring or early summer, a large percentage of trees, pruned to a single bud in order to form the natural head may fail to branch during the first season in the orchard. At the beginning of the second growing season such unbranched trees tend to form a structurally unsound type of head in which the branches form a whorl at one point on the trunk. In the case of trees trained to a vase form, poor growth results in a head with too few main scaffold branches. For both types of trees the period of profitable fruit production is considerably delayed.

In 1943, 18 budded trees were transplanted, pruned to vase form and grown under exceptionally favorable conditions. They were watered the first few days, and then hand-hoed frequently the remainder of the season. Moderate applications of fertilizer were made on three different dates. Although the trees made exceptionally vigorous growth, an initial rapid rate of growth at the beginning of the growing season was followed by a decline beginning the middle of May and lasting into June. Minimum rate of growth was followed in late June by an abrupt increase which attained a peak by the middle of August and tapered off in September as the fall droughts set in. The greater portion of the total linear growth took place in only three out of seven frost-free months.

Under less favorable culture, the check in growth is more serious and recovery comes slowly if at all. Several examples may be cited. In 1944 some 1200 trees were planted in an orchard near Cairo, Georgia, and trained to single buds. They were adequately fertilized with 1¼ pounds of 4–8–6 fertilizer per tree but, due to factors beyond the grower's control, received very little cultivation or hoeing. The first year's growth was very disappointing and in order to avoid structurally unsound trees it was necessary to cut the trees back to 14-inch stumps and train to the vase form at the beginning of the second growing season.

Observations were made on another lot of some 300 vase-form tung trees which formed part of a 90-acre commercial orchard planted in 1944 near Lloyd, Florida. Due to the pressure of other work the grower failed to cultivate the trees during the critical spring drought period. Lack of soil moisture was evidenced as early as May 9 by severe wilting of succulent weeds. The wilting of weeds and visual inspection of the soil indicated that the deficiency of moisture persisted

until the summer rains began on July 3. Periodic measurements showed an early rapid daily rate of growth, which dropped off with the cessation of the heavy spring rains and the coming of warm spring weather in early May. The trees failed to recover, growth was very disappointing the first year, and considerable corrective pruning was necessary because many trees had formed only two or three main scaffold branches.

A small-scale fertilizer test was conducted on newly transplanted trees in 1944 in the hope that the proper application, correctly timed, might prevent the slump in growth or at least promote recovery. The daily rate of growth decreased with coming of the spring drought irrespective of the presence or absence of fertilizer. This excluded fertilizer burn as the primary cause of the reduced rate of growth in the early spring. There was evidence that time of application can be an important factor in bringing about the resumption of growth after the heavy summer rains begin. Trees receiving 1 pound of fertilizer May 17, during the early part of the drought, were significantly larger at the end of the season than those receiving 1 pound of fertilizer either April 12, before the drought, or June 20, just before the rains began. It was also observed that nursery trees of good caliper seemed to suffer less from the drought than those of small caliper. Fig. 1 shows

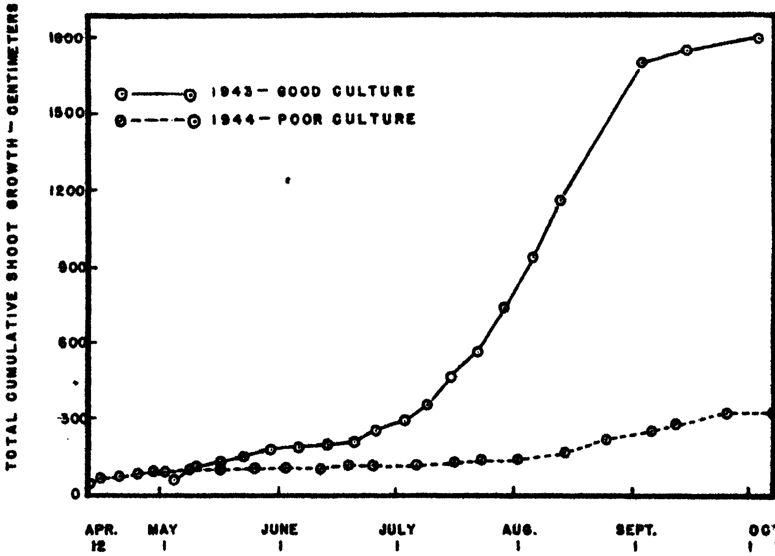

FIG. 1. Total cumulative shoot growth per tree in 1943 when effects of dry weather in early season were mitigated by good culture and in 1944 when under poor culture the trees failed to recover from the drought.

the average total linear growth for trees receiving 1 pound of fertilizer on April 12, which may be considered typical of growth under the conventional orchard practice of the district, as compared to that of the 18 trees previously described that were grown in an exceptionally

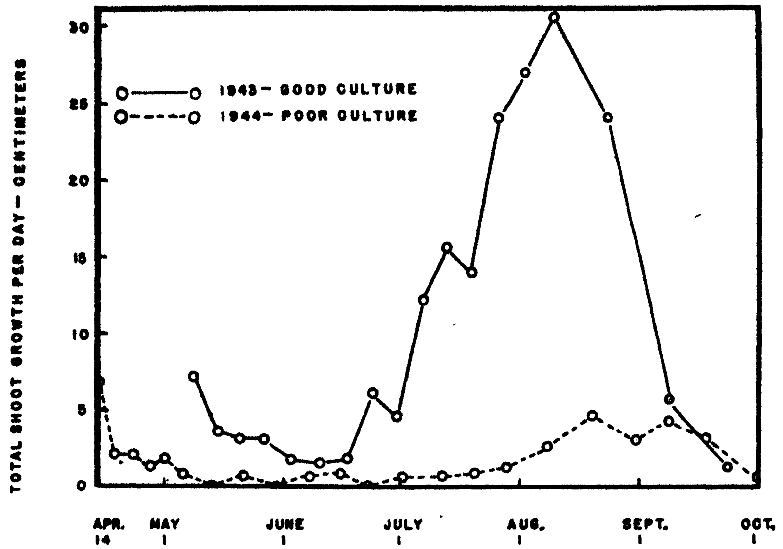

FIG. 2. Daily rate of shoot growth per tree throughout the season, under good culture in 1943, and under poor culture in 1944.

favorable environment. A calculated daily rate of growth for these two lots of trees is shown in Fig. 2.

The principal difference between the growth curves of 1943 and 1944 is that in 1943 recovery and good subsequent growth took place while in the other the drought directly hampered growth for a 2-month period and was apparently responsible for the failure of the trees to resume active vegetative growth with the coming of the July rains. Once the trees are so severely affected by drought that the younger leaves on the growing points become brown in color and tough and leathery in texture, immediate active vegetative growth may be impossible even though optimum moisture is supplied. Furthermore, if drought conditions are allowed to become the limiting factor in growth, the effect of fertilizer is partially or totally nullified.

It is evident that spring droughts occur frequently in southern Georgia and western Florida and that they are extremely detrimental to the growth of newly transplanted tung trees. The problem is to minimize the effect of the dry weather and to stimulate subsequent growth by (a) appropriate cultural practices, (b) well-timed fertilizer applications, (c) the use of adapted varieties, and (d) the use of well-grown nursery stock. The first two are of major importance.

Experimental Procedure

An experiment was set up in 1945 to study the four factors enumerated above. A split plot design was used in which the main plots consisted of three replications of two varieties, L–128 and F–99, in randomized block design.

Each main plot, which consisted of 48 trees of one variety, was subdivided into three cultural plots of 16 trees each, as follows:

(a) *Check or Conventional Practice:*—Harrowed four times, hoed two times. Weeds partially controlled.

(b) *Mulch:*—Same as above, except that each tree was mulched with 1 bushel of sawdust soon after planting. Weeds not completely controlled.

(c) *Frequent Cultivation:*—Disk harrowed 4 times, hoed 12 times. Weeds completely controlled.

Each cultural plot was divided into four fertilizer plots of four trees each. A total of 1 pound of 8–8–6 fertilizer per tree was to have been applied but by error the cooperator made a blanket application of 1 pound of 4–8–6 fertilizer to all trees on April 24. The additional applications of the 8–8–6 fertilizer were as follows:

(a) 1 pound March 16.
(b) ¼ pound March 16, ¾ pound July 23.
(c) ½ pound June 20, ½ pound July 23.
(d) 1 pound July 23.

Each fertilizer plot was planted with two trees of large caliper and two trees of small caliper.

Results

In 1945 the rainfall seemed adequate until May. On May 10 the soil appeared moist even at the surface, yet under all three cultural treatments tung trees were wilted. Evidently, transpiration losses were so great that the trees could not take up moisture from the soil in sufficient quantities to maintain normal turgor pressure, which was indicated by drooping of many of the succulent branch tips. Under the almost optimum moisture supply of early spring relatively extensive shoots and leaf areas are developed, probably utilizing reserve substances in the tree. As soil moisture decreases and the weather becomes hot, root systems, previously adequate, apparently are unable to meet transpiration requirements, which results in a check in shoot growth.

The length of shoots was measured at intervals of 2 to 3 weeks. During a period of 18 days ending April 30, trees in all plots attained an average rate of total shoot growth of about 2.22 to 2.56 centimeters per day. A decline set in in May and by June 9 the rate of total shoot growth in the check and mulched plots had diminished to 1.04 or 1.28 cm per day. In the plots cultivated frequently the minimum daily rate of total shoot growth recorded was 1.80 cm per day during the period ending May 15, and by June 9 a growth rate of 2.28 cm per day had been regained.

The trees were scored in June for symptoms of zinc deficiency, using a scale of one to four, in which one represented trees free or practically free from the disorder and four represented trees exhibiting marked symptoms. The average scores for check, mulched, and frequently cultivated trees were, respectively, 1.62, 1.70, and 2.36. The difference in incidence of zinc deficiency symptoms between the trees frequently cultivated and the other two treatments is statistically sig-

TABLE I—EFFECT OF INTENSIVE CULTIVATION AND OF MULCHING ON GROWTH OF BUDDED TUNG TREES OF THE CLONES F-99 AND L-128, THOMASVILLE, GEORGIA, 1945

Date of Measurement and Final Date for Each Growth Period	Cultural Treatments					
	Mulch* Mulched with 1 Bushel Sawdust Per Tree (Weeds Partially Controlled)		Check 4 Disk Harrowings and 2 Hand Hoeings (Weeds Controlled)		Frequent Cultivation* 10 Extra Hand Hoeings (Weeds Completely Controlled)	
	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)
Mar 27	4.5	——	4.2	——	4.1	——
Apr 12	23.0	1.16	21.0	1.05	19.0	0.93
Apr 30	65.0	2.33	61.0	2.22	65.0	2.56
May 15	89.0	1.60	85.0	1.60	92.0	1.80
Jun 9	121.0	1.28	111.0	1.04	149.0	2.28
Jun 30	152.0	1.48	131.0	0.95	217.0	3.24
Jul 23	367.0	9.35	255.0	5.39	583.0	15.91
Aug 2	559.0	19.20	365.0	11.00	806.0	22.30
Aug 21	996.0	23.00	663.0	15.68	1385.0	30.47
Sep 20	1319.0	10.77	916.0	8.43	1732.0	11.57
Oct 30	1352.0	0.82	932.0	0.40	1783.0	1.28

*Supplementary to the conventional four disk harrowings and two hand hoeings per season.

nificant at the .01 level. The total shoot growth up to June 30 was 131, 152, and 217 cm, respectively, for the three treatments. There may be a greater zinc requirement associated with rapid growth.

The effect of the cultural treatments throughout the season is summarized in Table I. It may be noted that by October 30 average total shoot growth of the control trees was 932 cm per tree while that of the trees hoed frequently was 1783 cm, a gain of 91.0 per cent. Trees mulched with sawdust made an intermediate growth, 1352 cm. These differences are supported by very high odds. Constant stirring of the soil in all probability conserved moisture, promoted absorption by improving the physical condition, and reduced run-off. Favorable conditions for biological activity in the soil probably were produced and minerals may have been rendered available. Certainly the fertilizer applications were more thoroughly incorporated with the soil and loss of fertilizer by surface washing was reduced to a minimum. However, there was no statistically significant interaction between culture and time of application of the fertilizer.

The use of a single bushel of sawdust as a mulch around each tree was also highly beneficial. Sawdust would tend to conserve soil moisture although light showers might not penetrate it. The sawdust mulch could favorably influence physical and chemical properties of the soil as well as its flora. The sawdust tended to control weed growth for a radius of 1 foot around the tree, the extent of the mulch.

Growth of the trees was depressed by heavy early applications of fertilizer. The cooperator's application of 1 pound of 4-8-6 on April 24 undoubtedly still further decreased growth of trees to which 1 pound of 8-8-6 was applied on March 16, but its effect on those trees that were scheduled to receive only the late application was probably even greater. From a statistical point of view the average shoot growth

of 1218 centimeters per tree resulting from the earliest application is significantly lower than that produced by the three other schedules.

On March 27, growth of the F–99 trees greatly exceeded that of the L–128, but by the end of the season the early advantage of the F–99 had been leveled out. Nor did either variety exhibit a specific response to any of the various treatments in the experiment.

Nursery stock of large diameter gained an early lead in shoot growth over stock of small caliper. On March 27, the difference was statistically significant at the .01 level and by October 30 the average readings for total shoot growth were 1516 and 1196 centimeters, respectively, for the large and the small nursery stock. The value of F for this difference is 58.35 where 12.61 is required at the .001 level. This response had previously been observed when newly planted tung trees were trained to vase form. It has not occurred with trees trained to a single bud so as to form the natural-head type of tree.

Signs of nitrogen deficiency appeared towards the end of the growing season. On October 17 it was observed that some trees were comparatively pale in color and gave the appearance of nitrogen deficiency. All trees were scored on the basis of color, on a scale of one to four, in which a score of one represented a pale green color and a score of four indicated a dark green color. Trees under sawdust mulch had the lightest colored leaves, with an average score of 2.29. The check trees were significantly darker in color, with an average score of 2.73, while leaves of the trees frequently hoed scored 3.16 which in turn exceeded that of the check trees by a margin statistically significant at the .05 level. No extra nitrogen was supplied to the mulched trees; hence it is likely that organisms decomposing the sawdust competed with the trees for the nitrogen of the soil.

On October 17 a leaf disorder that caused the more mature leaves to be heavily spotted with small dark areas was also scored. This condition has sometimes been called "pepper spot" and, when previously observed, had occurred on 1-year trees that had grown rapidly. The trees were scored on a scale of one to six in which a score of one represented a lightly affected tree and a score of six indicated that all leaves were heavily affected. It was found that incidence of the disorder had been affected by fertilizers but not by culture. The average score for trees receiving all the fertilizer on March 16 and April 14 was 3.75, whereas the averages for the other three schedules of application ranged from 2.39 to 2.62. The differences required for statistical significance at the .05, .01, and .001 levels are, respectively, 0.52, 0.17 and 0.94. It is evident that the disorder was associated with the heavy early fertilizer application, which in this case depressed rather than stimulated growth.

It might be anticipated that overstimulation of growth would result from certain treatments and that the consequent immaturity of the wood might render the trees susceptible to cold in early fall. Tables I and II show that the maximum daily rate of growth in all treatments occurred during the period ending August 21. The rate declined rapidly in all plots during the two successive periods ending respectively September 20 and October 30. The decline was proportionately most

TABLE II—EFFECTS OF TIME OF APPLICATION AND AMOUNTS OF FERTILIZER ON GROWTH OF BUDDED TUNG TREES OF THE CLONES F–99 AND L–128, THOMASVILLE, GEORGIA, 1945

Date of Measurement and Final Date for Each Growth Period	Amounts of 8–8–6 Fertilizer Applied Per Tree*							
	1 Pound March 16		½ Pound March 16 ½ Pound July 23		½ Pound June 20 ½ Pound July 23		1 Pound July 23	
	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)	Total Linear Growth (Cm)	Calculated Daily Rate of Growth (Cm)
Mar 27...	3.8	——	3.7	——	4.7	——	4.8	——
Apr 12...	21.0	1.08	20.0	1.02	22.0	1.08	21.0	1.01
Apr 30....	65.0	2.44	66.0	2.56	62.0	2.22	61.0	2.22
May 15..	87.0	1.47	94.0	1.87	88.0	1.73	86.0	1.67
Jun 9....	120.0	1.32	130.0	1.44	130.0	1.68	128.0	1.68
Jun 30...	158.0	1.81	170.0	1.90	178.0	2.29	160.0	1.52
Jul 23....	381.0	9.70	401.0	10.04	434.0	11.13	391.0	10.04
Aug 2....	567.0	18.00	582.0	18.10	624.0	19.00	534.0	14.30
Aug 21...	961.0	20.74	1022.0	23.16	1088.0	24.42	987.0	23.84
Sep 20...	1213.0	8.40	1368.0	11.53	1378.0	9.67	1330.0	11.43
Oct 30...	1218.0	0.12	1418.0	1.25	1410.0	0.80	1376.0	1.15

*In addition the cooperator inadvertently fertilized all trees with 1 pound of 4–8–6 fertilizer on April 24.

rapid with those trees hoed frequently, which by September 20 had dropped to about one-third the peak rate. At that time the check and mulch treatments had dropped to about half their peak rates.

To obtain further evidence on this matter, the growing points on each tree were counted and the average growth per shoot for the period August 21 to October 30 was computed. The trees frequently cultivated had the most growing points and the average growth per shoot was only 9.15 cm as opposed to 10.04 and 10.41, respectively, for mulched and check trees. This difference is not statistically significant at the .05 level, but if the linear growth per bud during late August, September, and October can be considered a reasonable criterion for wood maturity, the trees grown under the cultural conditions producing the greatest amount of total growth for the year were fully as well matured as check trees making little more than half as much total linear growth. One can not assume that poor total growth means cold-resistant wood. Trees checked in growth by drought and poor cultural conditions might under certain conditions resume active vegetative growth at a dangerously late date. In 1945 none of the experimental trees suffered cold injury, though succulent growth forced by pruning an adjacent border row of trees in August was killed by an early winter freeze.

The data also gave some evidence that, as might be expected, July fertilizer applications tended to prolong growth in fall. During the period August 21 to October 30 the trees fertilized with one pound of 8–8–6 in July made 10.76 cm growth per shoot, as opposed to 8.65 for those not fertilized after April 24, a difference statistically significant at the .01 level.

Summary and Conclusions

1. Although the average annual rainfall is about 50 inches in southern Georgia and western Florida, spring droughts occurred that were extremely detrimental to the growth of newly transplanted tung trees in 1943, 1944, and 1945.

2. Even under otherwise most favorable growing conditions, the rate of growth declined during the dry weather.

3. Hoeing the trees 10 extra times, as a supplement to the standard practice of four disk harrowings and two hoeings, minimized the effect of dry weather on the growth rate and effected an average total shoot growth for the season of 1783 cm per tree, which was 91 per cent greater than that of trees receiving the standard culture only. The growth matured satisfactorily before cold weather set in.

4. Mulching with 1 bushel of sawdust per tree was less effective than hoeing, but increased the growth rate during dry weather somewhat and effected a total shoot growth for the season of 1352 cm per tree, 45 per cent greater than that of the checks. Leaves of the mulched trees were pale green in color toward the end of the season.

5. Heavy early applications of fertilizer tended to aggravate the effect of drought on growth rate and significantly decreased total shoot growth for the season. They also increased the incidence of a foliage disorder known as "pepper spot".

6. Late fertilizer applications had a tendency to promote late fall growth, but did not cause the trees to suffer cold injury.

The Effect of Cultivation, Watering and Time of Fertilization on the Growth of Transplanted One-Year-Old Tung Trees

By JOSEPH HAMILTON and MATTHEW DROSDOFF
U. S. Department of Agriculture, Beltsville, Md.

THE difficulty of establishing vigorous young tung trees (*Aleurites fordii* Hemsl.) on the Norfolk fine sand soils in the vicinity of Ocala, Florida, has been recognized by both growers and research workers. Experimental plantings set out on different sites in the Ocala area during four different seasons (1941 to 1944, inclusive) either have been total failures or have made very unsatisfactory growth in spite of careful planting, what was considered to be adequate cultivation, and liberal fertilizer applications. Commercial plantings have been equally unsatisfactory. The problem of poor tree development is not limited to the Ocala area alone, but widespread uniformly unsatisfactory results are not often observed elsewhere in the tung belt.

Many factors have been suggested as possible causes of the trouble including orchard management practices, soil moisture relations, time and amount of fertilizer applied and deficiencies of certain essential elements. In an effort to determine just what the limiting factors were in the growth of transplanting tung seedlings on the Norfolk fine sand in the Ocala area, an exploratory experiment was undertaken on a site where plantings had failed in each of the two preceding seasons. After thorough consideration it was decided to try (a) frequent cultivation as compared to conventional practice, (b) watering of the trees during dry weather and (c) applying the fertilizer only after the tree has become well established to avoid possible injury to the roots of the newly set tree.

EXPERIMENTAL PROCEDURE

In an effort to determine just what the limiting factors are in the growth of transplanted tung seedlings on the Norfolk fine sand in the Ocala area, an exploratory experiment was undertaken on a site where plantings had failed in each of the two preceding seasons. On March 13, 1945, 1-year-old seedlings were planted 5 feet apart in rows 30 feet apart. A 6-foot strip of soil along the row had been disk-harrowed three times before planting and, since the soil was very dry, the trees were watered well when plantd. All trees were cut back to 6 or 8 inches and one bud was allowed to develop. The planting was divided into 24 plots of four trees each, with a guard tree between plots in the row. Twelve treatments were assigned to the plots, thus permitting two replications in randomized block design. Eight of the treatments consisted of the factorial combinations of three pairs of factors as follows:

Cultivation:—Spading seven times versus hoeing a 3-foot radius around each tree twice, both as supplements to the usual three to four disk harrowings per season.

TABLE I—TREATMENTS AND SCHEDULE OF OPERATIONS IN THE FACTORIAL EXPERIMENT INVOLVING THE FACTORS OF CULTIVATION, WATERING, AND FERTILIZATION

Treatment	Dates and Operations Performed*										
	March 20	March 28	April 4	April 12	May 9	May 22	June 5	June 21	July 9	July 20	August 21
						*Cultivation***					
Frequent....	Spaded	—	—	Spaded	Spaded	Spaded	Weeds hoed	Harrowed	Spaded	Harrowed and spaded	Spaded
Infrequent ..	—	—	—	—	—	—	Weeds hoed	Harrowed	—	Harrowed and hoed	—
						Watering†					
Frequent....	Watered	Watered	Watered	—	Watered	Watered	Watered	—	—	—	—
None........	—	—	—	—	—	—	—	—	—	—	—
						Fertilization (Pounds)††					
Early........	—	—	½	—	—	¼	—	—	—	¼	—
Late........	—	—	—	—	—	½	—	—	—	¼	¼

*The whole area was disk-harrowed 3 times on March 13, before planting on that day.

**For frequent cultivation the entire four-tree plot, an area approximately 6×20 feet was spaded. The harrowing was done with a common tractor disk harrow along the rows, but not across the rows.

†Twelve to 15 gallons of water per tree was applied in a basis about 2 feet in radius. After June 15 the heavy summer rains kept the soil at optimum moisture.

††The fertilizer used was a 6-6-6 commercial mix containing 3 per cent MgO, 1 per cent ZnO, 5 per cent MnO and .5 per cent CuO, all as sulfates.

Watering:—Applying 12 to 15 gallons of water per tree every 2 weeks, unless the soil was wet from recent rains, versus no watering.

Fertilization:—Applying a total of 1 pound of 6–6–6 mixed fertilizer per tree in three applications beginning only after the tree was well established, versus three applications beginning 2 weeks after planting.

The schedule of operations for these eight treatments is shown in Table I. Four other treatments, which it was believed might produce satisfactory growth, were tried as follows:

Colloidal Phosphate:—Before the tree was planted, approximately 30 pounds of coarsely ground colloidal phosphate (Calphos) was well spaded into the soil in the bottom of the tree hole and about 3 gallons of water added. The tree was then planted and 30 more pounds of colloidal phosphate was mixed with the soil that was filled in around the roots. About 3 more gallons of water were poured in as the tree was planted. The colloidal phosphate was used with the idea of increasing the water holding capacity of the soil. It had been reported by other growers as being beneficial with newly transplanted tung trees.

Peat:—Half as much peat by weight was substituted for the Calphos, and the trees were planted and watered in the same manner as those that received the Calphos treatment.

Pine Straw Mulch:—An area about 4 feet in diameter around each tree was mulched with pine straw about 8 to 10 inches deep soon after the trees were planted. This mulch was renewed as the season progressed, but apparently was not heavy enough to completely suppress weed growth.

Manure Mulch:—On May 9, 30 pounds of dry stable manure was applied as a mulch to an area 3 feet in diameter around each tree.

The trees in these four treatments received the conventional cultivation, were not watered subsequent to planting, and the fertilizer was applied after the trees had become well esetablished.

Shoot measurements were made on May 9, June 5, July 9, August 21, and September 27. On the last date the circumference of the trunk was determined 15 cm above the point at which new growth had started.

Results

The data for the growth measurements on the different dates are given in Table II and the statistical treatment of the data is given in Table III. For August 21 and September 27 a calculated size of top is given in Table II instead of the shoot growth, since it is believed that this value represents the development of the trees more accurately than does the total shoot growth. The calculated size of top is the length of the trunk plus one-half the length of the primary branches, if there were any on the tree. This will be designated *"weighted top growth"*.

The data in Table II show that the trees passed through three stages during their first season of growth. During the first stage, a period of about 2 months from the date of planting, the trees all made about the same amount of growth regardless of treatment (see length of trunk May 9). The trunk growth was not affected by cultivation

TABLE II—EFFECTS OF CULTIVATION, FERTILIZATION, IRRIGATION, AND OTHER TREATMENTS ON GROWTH OF ONE-YEAR-OLD TUNG TREES TRANSPLANTED MARCH 13, 1945, OCALA, FLA.

Treatments				Length of Trunk (Cm)			Weighted Top Growth (Cm)*		Cross-Section of Trunk (Square Cm)
Cultivation	Fertilization	Times Watered	Supplementary Application	May 9	Jun 5	Jul 9	Aug 21	Sep 27	Sep 27
Infrequent	Late	None	———	20.9	24.3	30.2	62	81	1.08
Frequent	Late	None	———	23.2	29.8	52.2	165	292	4.75
Infrequent	Early	None	———	19.8	20.0	25.4	41	51	0.69
Frequent	Early	None	———	24.4	29.5	48.2	127	229	3.05
Infrequent	Late	Six	———	21.0	27.6	47.1	84	132	1.94
Frequent	Late	Six	———	22.2	36.8	75.6	233	351	5.82
Infrequent	Early	Six	———	25.4	40.2	57.9	84	132	1.52
Frequent	Early	Six	———	23.4	46.0	87.8	266	330	4.57
Infrequent	Late	None	Colloidal phosphate	26.6	31.0	41.4	114	152	2.02
Infrequent	Late	None	Peat	19.8	22.7	29.8	53	64	1.01
Infrequent	Late	None	Pine mulch	21.6	26.2	34.8	66	86	1.32
Infrequent	Late	None	Manure mulch	21.2	23.8	36.5	94	142	1.96

*Weighted top growth is the length of the trunk plus one-half the length of the side branches, if any.

or fertilization and is presumed to have developed from reserves within the plant.

The second stage, a period extending from about May 9 to about June 5, was characterized by the predominant effect of watering. By June 5 the average trunk growth of the watered trees was 37.7 cm, while that of the unwatered trees was 25.9 cm. On June 5 the fertilizer treatments were, for practical purposes, a comparison of presence and absence of fertilizer, since the late application had been made only 2 weeks previously. The statistical analysis (Table III) indicates a highly significant interaction between watering and fertilizer; hence it is necessary to study the interrelation of these two factors. If extra water was applied the early fertilizer increased growth of the trunks from 32.2 to 43.1 cm, a difference that has high statistical significance; but it may have been harmful when no water was applied, as it reduced trunk growth from 27.0 to 24.8 cm, a difference without statistically significance. Since the analysis indicates no interaction whatever between cultivation and fertilizer, the effect of the fertilizer on unwatered trees was the same whether cultivated frequently or not. On June 5, the response to cultivation was less than to watering but was also highly significant statistically.

The third stage is presumed to extend from mid-June when the summer rains began to the end of the season. During this stage the effect of frequent cultivation became increasingly predominant, resulting in tree growth several times that of the infrequently cultivated trees, which averaged only 100 cm in weighted top growth at

TABLE III—TREATMENT, MAIN EFFECTS AND INTERACTIONS BASED ON DATA IN TABLE II AND THEIR STATISTICAL SIGNIFICANCE AS DETERMINED BY ANALYSES OF VARIANCE EXPRESSED ON A PER TREE BASIS

Treatment Effects	Length of Trunk (Cm)			Weighted Top Growth (Cm)		Cross-Section of Trunk (Square Cm)
	May 9	June 5	July 9	August 21	Sep 27	Sep 27
			Main Effects			
Cultivation	1.5	7.5	25.8	127	201	3.24
Fertilization	−1.4	−4.3*	−3.6*	−4	28	0.94
Water	0.9	11.8	28.1	71	74	1.07
			First Order Interactions			
Cult.×Fert.	−0.2	0.2	0.6	1	−13	−0.54
Cult.×Water	−1.9	0.0	3.4	32	8	0.22
Fert.×Water	1.4	−6.6	−8.0	27	18	0.10
			Second Order Interaction			
Cult.×Fert.×Water	−1.4	−1.8	0.2	9	3	0.12
			Mean of All Treatments			
	22.5	31.8	53.0	135	201	2.93
			Significance Levels			
0.05	—	4.4	12.0	46	53	0.72
0.01	—	6.5	17.9	68	81	1.07

*Since it was found that on June 5 and July 9 the fertilizer had increased growth of the irrigated trees and decreased that of the non-irrigated, the main or over-all effects on these dates are without significance.

the end of the season, whereas the frequently cultivated trees averaged 300 cm, which is very satisfactory for 1-year-old trees.

At the beginning of the third stage the watered trees were larger than those unwatered and this beneficial effect of supplemental watering continued throughout the third stage although it was overshadowed by the effect of cultivation. The maximum difference due to watering was observed September 27, when the watered trees averaged 238 cm in weighted top growth while the unwatered trees averaged 164 cm. However, late in the season variations due to uncontrolled factors were relatively large and hence the effect of watering by September 27 showed statistical significance at only the .05 level. The smaller actual difference of 28.1 cm growth observed July 9 has statistical significance at the .001 level.

By the end of the season the interaction of watering with fertilization had nearly disappeared and the trees fertilized late were somewhat larger than those fertilized early, regardless of watering. By September 27 the late fertilization had resulted in an increase of the cross-sectional area of the trunks of trees frequently cultivated from 3.81 to 5.28 square cm, but the increase of the infrequently cultivated trees was only from 1.10 to 1.51 square cm. There was a similar but less marked trend in weighted top growth. However, on September 27 the over-all gain of late over early fertilization in weighted top growth failed to attain statistical significance and that in cross-sectional area of trunk was significant only at the .05 level.

As for the supplementary treatments, both the colloidal phosphate and the manure mulch treatments appeared to be better than the standard treatment of infrequent cultivation, late fertilization, and no supplemental water. They were, however, not nearly so good as the average of the frequently cultivated trees.

Discussion

On the basis of the data obtained in this experiment there is little doubt that 1-year-old tung trees when planted on Norfolk fine sand in the Ocala area can be made to grow satisfactorily the first season following transplanting. The past failures may be attributed primarily to improper cultivation. The difficulty is most likely due to failure of the disk harrow to reach close to the trees, but the cultivation may have been too infrequent or possibly wrongly timed, or ineffective because penetration was too shallow. The unsatisfactory growth of the trees in previous years may have been due to one or more of these faults in the cultural practices.

Although in this experiment the soil was spaded to a depth of 5 or 6 inches, it is possible that hoeing would be satisfactory. However, in a previous experiment in this area on the same soil, 90 per cent of the trees died after the end of the first growing season, even though a 3- to 4-foot-radius circle around each tree was kept free of weeds by hoeing. In a somewhat similar planting nearby, trees that had been cultivated survived without loss. This would appear to confirm the

importance of an adequate stirring of the soil in the growing of young trees in this area.

It is generally believed that the most important purposes of cultivation are weed control, the conservation of moisture, and improvement of the physical condition of the soil. In a test conducted by the senior author during the summer of 1943, stunted tung trees that had been planted in an Ocala orchard the previous spring were dug up and carried to the laboratory at Gainesville. Two lots of soil, one from the field in which the stunted trees had been growing and one from a field in which trees were making vigorous growth, were hauled to the laboratory. The trees that were brought from the Ocala orchard were divided into two groups, and one group was planted in each lot of soil. As the trees were transplanted in midsummer, it was necessary to water them frequently. By the end of the season the trees so transplanted had made significantly better growth than corresponding trees that had been left in the orchard at Ocala. Moreover, there was no indication of a significant difference in growth between the trees growing in the two different lots of soil, one of which was inherently more fertile than the other. Since the soil particles were agitated in the digging, hauling and transplanting operations and since the trees were frequently watered, it was concluded that either cultivation or supplementary watering or both were the important factors. Since supplemental watering in the present experiment was not nearly so beneficial as frequent cultivation, it is likely that moving and stirring the soil was an important factor affecting the growth of the trees.

In general the late fertilization seemed preferable to early fertilization although the differences are not in all cases statistically significant.

This experiment suggests that stirring the soil and keeping it entirely free of weeds may have beneficial effects other than merely conserving moisture and plant nutrients, and further studies are under way to obtain information on this question. It is planned to determine whether merely keeping the area free of weeds is as effective as stirring the soil. The determination of the optimum time and number of cultivations is another problem that will be considered. It would be perfectly feasible to work the tree rows with a light row-crop type of cultivator as frequently as they were spaded in this experiment. However, further investigations may show that only a relatively few efficient and properly timed cultivations are needed to develop very satisfactory trees.

Summary

Because of previous planting failures, an exploratory experiment was set up on Norfolk fine sand in the Ocala, Florida, area to determine what the limiting factors were in the growth of transplanted tung seedlings.

A 2 x 2 x 2 factorial design was used. The factors under study were: (a) watering versus no watering during the growing season, (b) frequent spading versus infrequent hoeing, and (c) early fertilization versus late fertilization.

It was found that by far the greatest response in tree growth was due to cultivation, and in every instance frequent cultivation (spading) produced satisfactory trees. Watering and late fertilization were beneficial but not in the same order of magnitude as the spading. Further studies are under way to get more information on the beneficial effects of cultivation.

Spectrographic Determination of Mineral Composition of the Tung Leaf as Influenced by the Position on the Plant

By A. T. MYERS and B. C. BRUNSTETTER,[1] *U. S. Department of Agriculture, Beltsville, Md.*

FOR the past 5 years the writers have been conducting a foliar analysis study of tung involving determination of nine elements by means of the spectrograph. The question of the influence of the position of the leaf on composition came up early in the work and it seemed desirable to obtain more information on this phase of sampling.

LITERATURE REVIEW

Published reports on the composition of single leaves as a function of their positions on the plant are few in number. There are only limited data for tung trees.

James and Penston (9) made analyses for potassium on single leaves of the potato plant. They found the extreme top and bottom leaves relatively low in this element. The older leaves were continually losing K while the younger leaves were showing continual increases.

James and Cattle (8) conducted a nutrient experiment with the broadbean in which they analyzed single leaves for K and Cl ions. In the complete nutrient solution they found that K increased from the apical leaf to the fourth leaf. In the fifth and sixth leaves K was constant, but it decreased to the tenth or basal leaf. When the nutrient solution lacked K, the K content decreased from apex to base.

Drosdoff (4) found that in the field basal leaves of tung trees were lower in K and P than mid-shoot leaves. The basal leaves, however, had a higher content of Ca, Mg, Fe and Mn.

Hammer, Street, and Anderson (7) as well as Swanback (10) have published single-leaf analyses of "Havana Seed" tobacco plants. After curing, composite samples were taken of all first leaves, all second leaves, and so on up to and including the sixteenth or top leaves. Proceeding from the bottom or oldest leaves to the top or youngest ones, there was a decrease in Ca and Mg and an increase in N. Potassium showed no regular trend.

Glenister (6), investigating the effects of Fe deficiency on respiration of sunflower plants, found a gradient of decreasing Fe content from the bottom to the top of the plant. No translocation of Fe from the older to younger leaves occurred.

METHODS

Plant Sample:—The seedling tree whose leaves were subjected to analysis was from a tung nutrition experiment conducted by C. B. Shear and H. L. Crane. The composition of the nutrient was as follows: 232 ppm of Ca, 81 of K, 48 of Mg, 162 of N (as nitrate), 81 of

[1]The authors wish to acknowledge the technical assistance of Jane L. Showacre in some of the analytical determinations, and the valuable criticism of Dr. H. L. Crane and C. B. Shear.

P, 30 of S, 153 of Cl, 60 of Na, 2.0 of Fe, 1.0 of Mn, 0.1 of B, 0.13 of Zn, and 0.06 of Cu. The plant had 2-liter portions of this solution administered three times a week.

The leaves from this 6-months-old seedling tree were harvested July 14, 1942, after it had grown in this nutrient solution for 90 days. They were numbered from 1 to 22, leaf No. 1 being at the bottom. Leaves 10 and 11 were not included in this analysis because they had been analyzed as a part of another sample. The leaves were weighed after drying to determine the total dry matter in each leaf. The dried samples were ground to pass a 30-mesh screen in a Wiley mill and then analyzed spectrographically.

Spectrographic Method:—The general method employed has been described elsewhere (3). Recent improvements have been made and were used in this study; the details of these will be published later.

Results

The results of the analysis given in Table I are expressed in milligrams and micrograms per gram of dry tissue for the major and minor

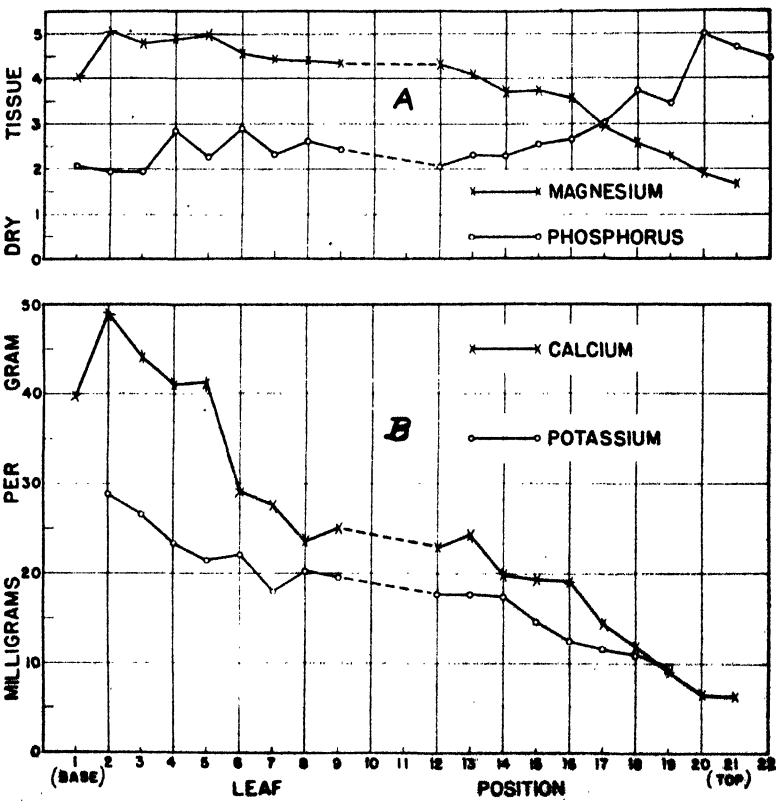

FIG. 1. Distribution of K, Ca, Mg, and P in successive leaves of a 6-months-old tung plant.

elements, respectively. Each result reported in Table I is the average of at least three determinations per leaf sample.

Major elements:—Fig. 1 shows the data for the elements Ca, K, Mg, and P in the form of curves, expressed as milligrams per gram of dry tissue. To read in terms of percentage simply divide by 10.

In Fig. 1–B a very decided upward trend with aging is shown by the calcium content. The concentration ranges from 0.6 per cent in the youngest leaf to 4.9 per cent in the next to oldest leaf. The oldest leaf (No. 1) has a slightly lower Ca content (4.0 per cent). Potassium undergoes a steady but less pronounced increase from the top leaf (0.9 per cent) to the next to basal leaf (2.8 per cent).

TABLE I—RESULTS OF A SPECTROGRAPHIC ANALYSIS FOR NINE ELEMENTS IN SUCCESSIVE LEAVES OF A TUNG PLANT*

Leaf Position (From Base to Top)	Milligrams per Gram				Micrograms per Gram				
	Mg	Ca	K	P	Mn	Fe	Al	Cu	B
1	4.00	39.7	—	2.06	300	375	910	9.2	125
2	5.08	49.0	28.7	1.94	279	269	650	7.4	68
3	4.80	44.1	26.5	1.94	262	240	575	7.9	67
4	4.90	41.0	23.3	2.85	279	215	530	8.0	62
5	5.00	41.3	21.4	2.27	253	218	465	5.8	93
6	4.57	29.1	22.0	2.90	220	197	410	5.1	65
7	4.44	27.7	17.9	2.34	248	159	285	6.2	59
8	4.44	23.6	20.4	2.62	235	163	250	6.4	53
9	4.34	25.0	19.5	2.45	208	129	225	8.6	75
12	4.32	22.8	17.6	2.07	203	112	150	8.4	36
13	4.10	24.4	17.6	2.30	210	98	118	6.5	38
14	3.72	19.9	17.1	2.30	195	90	100	5.7	32
15	3.75	19.3	14.6	2.54	176	90	84	4.7	26
16	3.58	19.1	12.4	2.66	187	91	82	4.7	23
17	2.95	14.3	11.5	3.00	136	76	53	7.5	21
18	2.58	11.8	10.9	3.72	105	72	58	7.3	20
19	2.28	9.0	9.5	3.45	77	66	44	6.9	16
20	1.89	6.4	—	5.01	55	79	56	12.0	15
21	1.64	6.2	—	4.70	45	78	—	14.5	19
22	—	—	—	4.45	—	—	—	—	19

*Each result shown above is the average of at least three determinations per single leaf sample.

Magnesium in the leaves shows a steady upward trend from 0.16 per cent in the uppermost leaf to approximately 0.5 per cent in the bottom ones (Fig. 1–A). The element P shows a reverse trend, starting initially in the top leaves at about 0.5 per cent and dropping off to about 0.2 per cent in the basal leaves.

Minor elements:—Fig. 2 shows the data for the elements Al, Fe, Mn, B, and Cu in the form of curves expressed as micrograms per gram (same as ppm).

In Fig. 2–B, Al shows a decided increase in concentration from around 45 to 60 micrograms at the top to 900 in the basal leaf. The leaves show a steady gain in Fe and Mn from apex to base of shoot. Iron increases from 70 to 375. Manganese increases from 45 to 300.

Fig. 2–A shows a very definite upward trend in the leaf concentration of boron, starting at about 15 ug in the top leaves and going to 90 and 125 ug in two of the bottom leaves. The copper content of the leaves does not show any very definite trend with the possible exception of one or two leaves at the top where a slight increase is indicated.

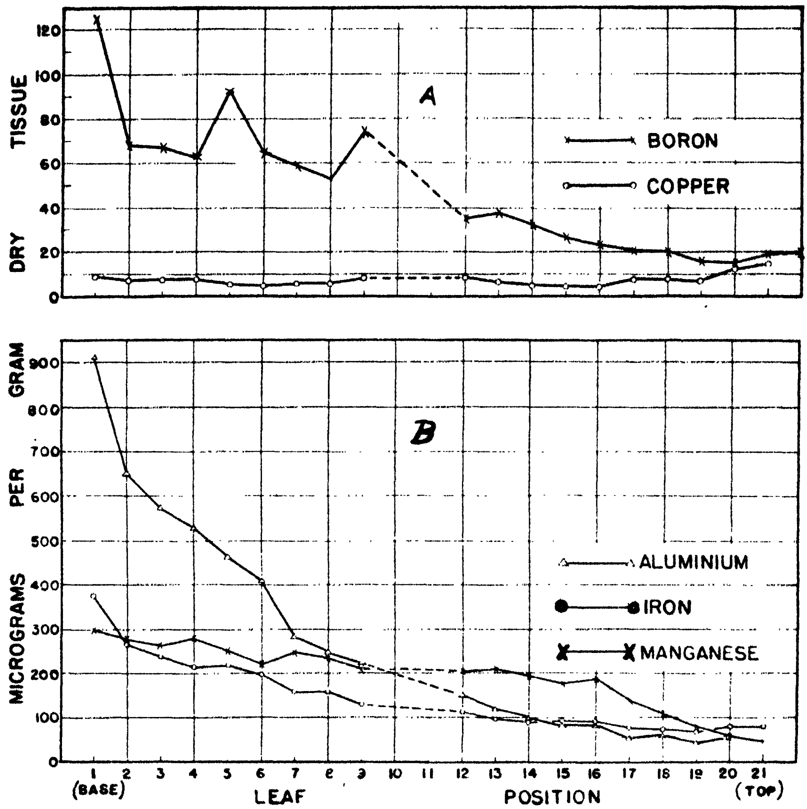

FIG. 2. Distribution of Al, Fe, Mn, B and Cu in successive leaves of a 6-months-old tung plant.

DISCUSSION

In sampling for tung nutrition experiments, the rule has been to take leaves from two middle nodes on the shoot for leaf analysis. According to our data this position for sampling is almost ideal, since it is obvious that if terminal or basal leaves were sampled such samples would show maximum concentrations for certain elements and minimum concentrations for others. The data show that of all the positions for leaf sampling this middle portion of the shoot is by far the best for comparative studies. Large changes in leaf composition due to leaf position are at a minimum in this region of the seedling plant and this undoubtedly applies in the field to shoots on mature trees.

According to the literature potassium is a very mobile element and under conditions of deficiency the trend seen in Fig. 1 probably would be reversed, so that the lower leaves would show the lowest concentration instead of the highest. The data of James and Cattle (8) would support this concept. The Ca and Mg trends shown here agree with

the data found in the literature in the case of tobacco (7, 10) and in the case of certain forest trees (2).

Biddulph (1) has shown by his radioactive phosphorus work on bean seedlings that P accumulation was greatest in the uppermost leaves. The present data would support this result.

Eaton (5), working on boron deficiency and toxicity, found that boron deficiency in sunflower and soybean is indicated by a dying of the stem tip and chlorosis of the young leaves. Boron toxicity in the sunflower is shown by a mottling of the older leaves at their tips and edges, followed by death of the tissue. The trend of boron content shown in the present data would thus confirm the localization of plant response for boron deficiency and toxicity, respectively, near the tip and the base of the leafy shoot.

Summary

The spectrographic method has proved useful where a strict economy of plant tissue was necessary in making an analysis of each leaf on a tung plant for nine elements.

It has been possible to show definite gradients in the concentrations of a number of elements in the tung leaf, according to the successive positions on the plant.

The best samples for comparison of effects of nutritional treatments on tung leaf composition are the fully expanded leaves from the middle nodes of the shoot.

In tung nutritional experiments a comparison of the composition of the bottom and top leaves on the same plant showed a greater difference for most elements than was found between the median leaves from plants subjected to widely different nutritional treatments. This, of course, merely reemphasizes the recognized importance of selecting leaves in similar stages of physiological development for making comparisons in composition.

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Vase-Form Training as a Corrective Measure for Potential "Cartwheel" Tung Trees

By JOHN H. PAINTER and MARSHALL S. NEFF,[1] *U. S. Department of Agriculture, Cairo, Ga.*

If tung trees pruned to one bud at planting time fail to branch the first season, they almost invariably throw out a whorl of branches from the terminal group of buds when growth begins the second season. Such trees, commonly called "cartwheels", are weak in structure.

In February 1940, an experiment was set up at Lloyd, Florida, in a large orchard of seedlings, 80 per cent of which had failed to branch. These trees were the open-pollinated progeny of a single tree known as Florida 9, resulting from seed planted in place. To determine the best corrective pruning for the unbranched whips, the following treatments were used:

(a) Control—no pruning; (b) cut back to 24 inches and trained to one bud; (c) Cut back to 24 inches and allowed to develop with no further pruning; (d) Cut back to 12 inches and trained to one bud; (e) Cut back to 12 inches and allowed to develop without further pruning; (f) Headed back about 3 inches and notched above buds where scaffold branches were desired.

Painter and Sharpe (1) have previously reported that during the 1940 season these natural-head trees, resulting from training to one bud, branched well but were extremely high headed, (treatments b and d), while those cut back to 12 inches or 24 inches without further pruning formed very satisfactory low vase-form trees, (treatments c and e). The number of buds forced on the notched trees proved inadequate. The unpruned control trees all formed the "cartwheel" heads. The purpose of this paper is to report subsequent growth and yield of these trees.

In accordance with the conventional commercial practice, suckers have been removed annually from the natural-head trees but were allowed to develop on the other forms. It has been observed that through growth of suckers the control trees have tended to approach the vase form. The same is true of the notched trees. The owner of the orchard in which this experiment was located, followed the practice of removing the suckers from "cartwheel" trees adjacent to the experimental plots, and in 1944 and 1945 yields of such trees were recorded (Treatment AA). Data on the production of air-dry fruit for the seasons 1942–1945 inclusive are shown in Table I.

It may be readily seen that the delayed vase trees[2] have consistently outyielded the other trees. Treatment F, which, as previously stated, is for all practical purposes a vase-form tree, is third in rank with respect to total yields for the period under study; and treatment A, the control, is in fourth position. Treatments B and D, representing the

[1]The authors are indebted to Dr. George F. Potter for assistance in the statistical work incorporated in this paper.

[2]Trees trained to one bud at planting time, then cut back to form the vase form at the beginning of the *second* season in the orchard are termed *"delayed vase trees"*.

TABLE I—EFFECT OF METHOD OF PRUNING IN 1940 ON YIELDS IN 1942 TO 1945, INCLUSIVE, OF SEEDLING TUNG TREES OF F-9 PARENTAGE, PLANTED AT LLOYD, FLORIDA, IN 1939

Method of Pruning in 1940	Form of Head	Annual Yield Air-Dry Fruit Per Tree (Pounds)				Total Yield Per Tree 1942–45, Inclusive (Pounds)
		1942	1943	1944	1945	
AA* Control, no pruning except removal of suckers	"Cartwheel"	**	**	10.1	29.3	—
A Control, no pruning	"Cartwheel"	4.6	11.9	10.8	32.1	59.4
B* Cut to 24 inches, allowing one bud to develop	Natural-Head	3.0	6.8	7.4	16.9	34.1
C Cut to 24 inches, allowing all buds to develop	Delayed vase†	6.8	23.9	16.8	38.8	86.3
D* Cut to 12 inches, allowing one bud to develop	Natural-Head	3.2	6.4	7.5	17.8	34.9
E Cut to 12 inches, allowing all buds to develop	Delayed vase†	6.3	28.2	21.1	38.8	94.4
F Cut back 3 inches, buds notched to force lateral branches	Artificial delayed vase†	5.0	14.9	15.5	28.9	64.3

*Suckers from near base of the tree have been removed annually.
**No record.
†Trees trained to vase form during the second season in the orchard are termed "delayed vase" to distinguish them from trees trained to vase form at planting time.

natural-head form of training, have been consistently poorest throughout the entire experiment. The difference between the trees produced at the two heights of cutting used in this experiment, namely 12 inches and 24 inches, is negligible. In the case of the vase trees, the yields in 1945 were identical, and in the case of the natural-head trees, there was only 1 pound difference.

A statistical analysis of the yield data indicates that the differences between the treatments are supported by extremely high odds. When the interaction of replications with treatments is used as the error term, the value of F for treatments is 21.69 where 5.88 is required for significance at the .001 level. This error term is generally considered legitimate for extending the conclusions to other blocks, that is, to other orchards under similar conditions. Wilm (2) has suggested that in experiments replicated in time, the variance for treatments should be corrected by deducting $n\ s^2{}_{ty}$ where n is the number of years and $s^2{}_{ty}$ is the variance of the interaction of years with treatments. Using this more conservative procedure, F for treatments becomes 12.52, still well above that required at the .001 level.

The interaction of years with treatments may be used to test the effect of treatments "in the time dimension", that is, to determine whether the same responses may be expected in a different series of years. Following the procedure suggested by Wilm (2), an F value of 6.84 is obtained where 4.56 is required at the .01 significance level, which indicates that in general the results may be expected to hold in other seasons.

The interaction of years with treatments is itself highly significant statistically when tested with the appropriate error term; namely, the second order interaction of replications with years, with treatments. This indicates that the relative standing of the different treatments has not been the same throughout the period under study. To bring out any difference in yield trends, data on the gain in yield of the vase-

TABLE II—TRENDS IN YIELD OF "CARTWHEEL", DELAYED VASE-FORM, AND NATURAL-HEAD TUNG TREES, AIR DRY FRUIT PER TREE

Year	"Cart-wheel" (Pounds)	Natural Head* (Pounds)	Delayed Vase Form** (Pounds)	Gain of Delayed Vase Form Over			
				"Cartwheel"		Natural-Head	
				(Pounds)	(Per Cent)	(Pounds)	(Per Cent)
1942	4.6	3.1	6.6	2.0	43	3.5	113
1943	11.9	6.6	26.1	14.2	119	19.5	295
1944	10.8	7.4	19.0	8.2	76	11.6	157
1945	32.1	17.3	38.8	6.7	21	21.5	124
Total	59.4	34.4	90.5	31.1	—	56.1	—

*Average for Treatments B and D.
**Average for Treatments C and E.

form trees over those of the non-pruned and natural-head forms are presented in Table II. These data show that the vase form trees have consistently maintained their advantage in yield over the natural-head form, although with increasing age the difference in yield is a smaller percentage of the total yield. There is no evidence that the yields of the natural-head trees may be expected to equal those of the vase form in the near future. However, the difference between the vase-form trees and the "cartwheel" trees has declined rather consistently from 1943 to 1945. As has previously been noted, these non-pruned "cartwheel" trees are tending to approach the vase form by virtue of the sucker growth. Considering all the evidence it may reasonably be expected that vase-form trees will prove superior to natural-head and "cartwheel" trees in any series of years that covers the same range in age of trees.

It has not been possible to measure accurately the size of the trees in this experiment, but it is obvious on inspection of the plots that the production of fruit in all treatments is proportional to the size and bearing area of the trees. In 1944, extensive test plantings were made in which trees of a number of different budded varieties and seedling progenies were trained to the vase form and to the natural-head at planting time. At the end of the second growing season, it is evident that the vase-form trees have outgrown those of the natural-head form by a considerable margin; and proportionally high yields may be anticipated when the first commercial crop is harvested in 1946. It is more difficult to obtain a satisfactory vase-form tree when the training is done at planting time than when an established tree is cut back as was done in 1940 in the experiment reported above. Means of overcoming these difficulties are being studied, and it seems likely that vase-form training will prove best, not only as a corrective measure, but as a general practice.

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Mulching Effects on the Growth of Grafted Black Walnut Trees[1]

By Thomas G. Zarger, *Tennessee Valley Authority, Norris, Tennessee*

For the establishment of plantings of grafted trees of black walnut, *Juglans nigra,* the Tennessee Valley Authority recommends application and maintenance of a deep mulch on the surface soil around each tree. In the region of the humid southeast, mulch may benefit the tree through several recognized functions: (a) blanketing the surface and reducing extremes of temperature in the soil, (b) conserving moisture through reducing both direct evaporation from the soil and growth of weeds, with their excessive transpiration, (c) improving the soil gradually during the course of decomposition of the organic matter, and (d) preventing soil movement and surface washing. The composite of benefits from mulching black walnut is manifest in tree growth.

Several different mulching materials are commonly available to farmers in the Tennessee Valley. The practical question of what mulching materials are effective for growth of planted black walnut was the subject of a test initiated in the spring of 1941. The initial influence of mulch in this test planting during two years has been reported upon (1). Development of black walnut in this mulching test during 5 years is summarized in the present report.

The test was established on a Fullerton silt loam soil in an old field near Norris, Tennessee with the planting of 75 black walnut trees. These were 3-year-old stocks with one-year grafts of the following varieties: Booth, Hepler, Ohio, Rice, Susan, Wanda, Mintle, Thomas, and B–23. The last three varieties are considered especially promising selections; however, varieties are not under comparative test here. Around each newly planted tree, treatments were applied in a 3-foot-radius circle. Each tree received 1 pound of 4–8–4 fertilizer. Mulches were applied and maintained annually at a depth of 3 to 4 inches. Treatments included in the test were mulching with (a) broomsedge, also called yellowsedge bluestem *Andropogon virginicus,* (b) wheat straw, (c) well-rotted hardwood sawdust, (d) well-rotted pine sawdust, (e) new hardwood sawdust, (f) new pine sawdust, and (g) no mulching, or untreated check.

The grafts of several trees were killed during the winter of 1943 reducing the five year survival to an average of 75 per cent. Too few trees were planted in this mulching test to permit the use of survival as an index of development. Measurements included height and stem diameter taken at the end of the first, second, and fifth growing season. Surviving trees averaged 2.7 feet in height at time of planting; their diameter measured just above the graft union averaged 0.48 inch.

Development of trees of all varieties during the 5 years is summarized by averages given in Table I. By the end of the second year,

[1]This is a five-year report on a study carried on by the Investigations of Minor Forest Products Section, Department of Forestry Relations, Tennessee Valley Authority.

TABLE I—HEIGHT AND DIAMETER GROWTH OF WALNUT TREES DURING FIVE YEARS AFTER PLANTING, AVERAGED BY MULCHING TREATMENTS

Mulching Treatment	Height Growth			Diameter Growth, Five Years (Inches)	Number of Trees, Basis
	First 2 Years (Feet)	Next 3 Years (Feet)	Five Years (Feet)		
Broomsedge	1.8	2.2*	4.0*	1.28*	7
Wheat straw	1.8	2.0*	3.8*	1.22*	5
Old hardwood sawdust	1.6	2.0*	3.6*	1.04*	7
Old pine sawdust	1.8	0.9	2.7	0.85	8
New hardwood sawdust	1.4	1.1	2.5	0.70	9
New pine sawdust	1.4	1.0	2.4	0.75	9
Untreated, check	1.1	0.9	2.0	0.60	10
Standard deviation	0.7	0.5	0.7	0.25	—

*Significantly exceeds untreated, check, at P = 1 per cent.

height growth for all six treatments suggested mulching benefits, but no one was highly significant. Development for this period, reported previously (1), has been substantiated by tree growth in the succeeding 3 years. After 5 years trees mulched with broomsedge, wheat straw, or old hardwood sawdust surpassed trees not mulched to a significant degree in both height and diameter growth.

Broomsedge proved the best mulch tested. This grass which occurs commonly as an old-field cover in the Tennessee Valley can be clipped or mowed from many planting sites for convenient mulching. Wheat straw gave good results. It is recognized as a standard mulching material that is available on farms. Sawdust was questioned as a high cellulose material which might modify the biologic regime of the soil with adverse initial effects on the tree. Well-rotted sawdusts provided a fairly satisfactory mulch; hardwood material appeared to be superior

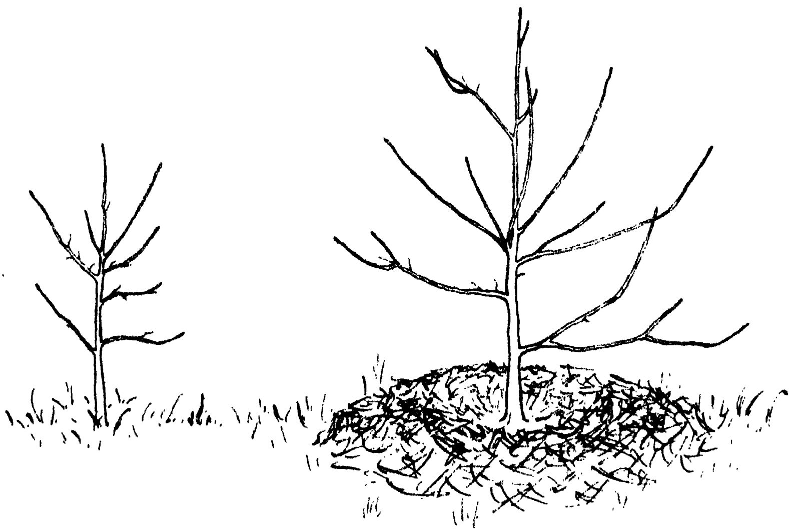

FIG. 1. Average trees of grafted black walnut 5 years after planting. Total height is 4.7 feet with no mulch, and 6.7 feet with broomsedge mulch

to pine. New sawdusts of hardwood and pine showed little benefit, but no adverse effects.

The beneficial influence of broomsedge mulching on average tree size after 5 years growth is shown in Fig. 1, in which tree dimensions are drawn to scale. The broomsedge mulch is diagrammed to show the depth and radius of mulching treatment maintained. Results available from the duration of this designed experiment and additional experience by TVA provides evidence that mulching benefits tree growth over a period of years.

Recommendation for mulching grafted black walnut trees are briefly stated as follows: (a) Use either a broomsedge or straw mulch. (b) Apply thick enough to give a settled depth of at least 4 inches in order to choke out weed growth. (c) Spread around tree in at least a 3-foot-radius circle but keep mulch away from tree trunk to avoid rodent damage. (d) Renew annually for several years extending radius of mulch as the tree crown increases.

Summary

Mulching of black walnut *(Juglans nigra)* was tested in a small planting at Norris, Tennessee, of trees of several varieties, including Thomas, Mintle, and B–23. Mulch of six different materials was spread in a 3-foot-radius circle about the tree and maintained at a 4-inch depth. Broomsedge *(Andropogon virginicus)* benefited trees the most in 5-year growth which amounted to 4 feet in height and 1.3 inches in diameter, compared with 2-foot height and 0.6-inch diameter growth of trees not mulched. Mulching benefits were significant for wheat straw and well-rotted hardwood sawdust; not significant for sawdusts of well-rotted pine, new hardwood, and new pine.

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Three Years' Results in Fertilization of Tung Seedlings in the Nursery[1]

By SAMUEL MERRILL, JR., *U. S. Department of Agriculture, Bogalusa, La.*, and S. R. GREER, *Mississippi Agricultural Experiment Station, Poplarville, Miss.*

INTRODUCTION

GERMINATION of tung seed and emergence of the seedlings from the soil is slow, requiring some 2 months. Emergence is followed by an initial period of 4 to 5 weeks of comparatively slow growth, after which there are 2 to 3 months of greatly accelerated growth, during which the trees respond readily to applications of fertilizer. Studies of the effect of fertilizers on the first year's growth of seedlings are of direct value in the management of tung nurseries and also may give important information on the requirements of the tung species, *Aleurites fordii* Hemsl. Tung nutrition is advantageously studied in the nursery because results are obtained quickly and since an experiment in a nursery occupies a relatively small area, errors due to soil variation are normally considerably less than in a similar test in the orchard. However, fruitbearing plays such a large part in the responses of the mature trees, and has such a profound effect upon nutrition, that the requirements of bearing trees may be expected to differ considerably from those of nursery trees.

For several years experiments on the fertilization of tung nurseries have been conducted at the Mississippi Experimental Tung Farm in Pearl River County, Mississippi, and Merrill, *et al.* (1) have reported that side dressing the young seedlings with 200 pounds per acre of an 8–8–6 fertilizer, applied either in the row before planting or as a side dressing after emergence of the seedlings, gave satisfactory results. The use of larger amounts of 8–8–6 or of supplements such as 650 pounds per acre of tung meal or the same amount of cottonseed meal, seemed of no advantage.

PLAN OF EXPERIMENT

In order to obtain more specific information on the relative value of different fertilizer materials and elements, more detailed experiments were set up in 1942, 1944, and 1945. In 1942 the tests involved (a) 1800 pounds per acre of poultry droppings, (b) 900 pounds per acre of "colloidal" rock phosphate, containing about 16 per cent P_2O_5, presumably as fluor apatite with some aluminum phosphate, (c) 225 pounds per acre of an 8–8–6 mixed fertilizer, and (d) combinations of these treatments. The poultry droppings and the rock phosphate were placed in a furrow and covered with 4 to 5 inches of earth, after which the seed were planted directly above the fertilizer. The 8–8–6 was worked into the soil as a side dressing.

In 1944 and 1945 three levels each of nitrogen, phosphorus, and

[1]Journal Article No. 115, New Series, Mississippi Agricultural Experiment Station.

potassium were used, alone and in factorial combinations. The low level of each element was that supplied by the soil, none being applied. At the intermediate level amounts equivalent to those contained in 250 pounds per acre of an 8-8-6 fertilizer were applied, and at the high level twice as much of each element was applied as at the intermediate level. In 1944 one-third of the nitrogen was supplied as nitrate of soda and the remainder as ammonium sulphate; in 1945 all the nitrogen was derived from ammonium nitrate. Phosphorus was supplied as 20 per cent superphosphate,[2] and potassium as 50 per cent muriate of potash. All materials were applied as side dressings and worked into the soil. The site of the experiment was different each season, but all the soils are classed as Ruston and the results are therefore representative of those to be expected on various phases of the Ruston series as they occur in Pearl River County, Mississippi. In all experiments seed were planted 2 inches deep and 6 inches apart in rows 5 feet apart; later the plants were thinned to approximately 1 foot in the row. Each plot consisted of 8 to 10 seedlings and the plots were separated by guard rows or by 3 to 4 guard trees in the row. In 1942 the trunk diameter and height of the trees were recorded at the end of the season. In 1944 and 1945 the trunk diameter and total linear growth of trunk and branches were measured. Samples of leaves from eight treatments representing the several combinations of the highest and lowest levels of nitrogen, phosphorus and potassium were taken in August 1944 and analyzed for mineral content.[3] The sample from each plot consisted of 20 leaves, two from each tree. In plots of less than 10 trees an extra leaf was taken from one or more trees to bring the sample up to the required number. Very few trees had branched at the time of sampling, and median leaves from the trunks were used.

Results and Discussion

The results in 1944 and 1945 will be considered first because they proved most informative as to the individual elements required by tung seedlings growing in these soils. A preliminary inspection and statistical analysis of the data (Table I) showed that nitrogen and phosphorus had effected significant growth responses, but potassium had not. The averages for total shoot growth of the trees grown at low, intermediate and high levels of potassium were, respectively, 135, 142, and 141 centimeters in 1944 and 137, 124, and 131 in 1945. The corresponding diameter measurements were respectively 1.77, 1.82, and 1.81 in 1944 and 1.45, 1.43, and 1.46 in 1945. Other evidence[4] indicates that many of the virgin soils of the western part of the tung belt can supply amounts of potassium adequate for good growth of

[2]An 18 per cent grade of superphosphate was inadvertently used in 1944 and consequently the formula for that season was actually 8-7.2-6.

[3]The writer is indebted to Dr. Matthew Drosdoff, Soil Technologist, U. S. Field Laboratory for Tung Investigations, Gainesville, Florida, for the leaf analyses.

[4]From experiments with newly transplanted trees to be reported later by Dr. B. G. Sitton, U. S. Field Laboratory for Tung Investigations, Bogalusa, Louisiana.

non-bearing tung trees. However, on certain soils the young trees respond to potassium and in the absence of specific evidence for the particular soil, it would be wise to include potassium in the nursery fertilizer as a means of insurance.

The data on the responses to nitrogen and phosphorus in 1944 and 1945 are shown in Table I. An interaction of nitrogen with phos-

TABLE I—RESPONSES OF TUNG SEEDLINGS TO NITROGEN AND PHOSPHORUS MEASURED AT END OF ONE SEASON'S GROWTH. MISSISSIPPI EXPERIMENTAL TUNG FARM—1944 AND 1945

Actual Nitrogen (Pounds Per Acre)	P_2O_5 Per Acre						Average for Nitrogen	
	None		20 Pounds*		40 Pounds*			
	Diameter (Cm)	Total Shoot Growth (Cm)	Diameter (Cm)	Total Shoot Growth (Cm)	Diameter (Cm)	Total Shoot Growth (Cm)	Diameter (Cm)	Shoot Growth (Cm)
Season of 1944								
None	1.35	85.2	1.61	103.2	1.56	105.6	1.51	98.0
20	1.87	137.4	2.00	178.4	1.92	162.0	1.93	159.3
40	1.82	145.8	1.90	138.2	2.15	198.2	1.96	160.8
Average	1.68	122.8	1.84	139.9	1.88	155.3	—	—
Season of 1945								
None	1.19	92.3	1.33	101.9	1.28	100.6	1.27	98.3
20	1.28	97.3	1.63	160.5	1.58	143.8	1.50	133.9
40	1.21	86.2	1.72	187.9	1.78	204.7	1.57	159.6
Average	1.23	92.0	1.56	150.1	1.55	149.7	—	—

	Least Significant Differences 1944				Least Significant Differences 1945			
	Diameter		Shoot Growth		Diameter		Shoot Growth	
	0.05 Level	0.01 Level	0.05 Level	0.01 Level	0.05 Level	0.01 Level	0.05 Level	0.01 Level
Combinations of nitrogen with phosphorus	0.20	0.27	33.8	44.8	0.14	0.19	32.4	42.9
Over-all effects nitrogen or phosphorus	0.12	0.16	19.4	25.8	0.08	0.11	18.6	24.6

*Respectively 18 amd 36 pounds per acre in 1944.

phorus, statistically significant at the .05 level, was observed in 1944 and it may be noted that the maximum average growth, 2.15 centimeters diameter and 198.2 centimeters total linear growth, was obtained only when the highest levels of these two elements were used; namely, 40 pounds of actual nitrogen and 36 pounds of P_2O_5 per acre. However, in this instance 20 pounds of nitrogen per acre effected significant increases in diameter and total shoot growth, even when no phosphorus was applied, and 36 pounds of P_2O_5 per acre effected significant gains in growth even when no nitrogen was applied. Very good growth, 2.00 centimeters average diameter and 178.4 centimeters average shoot growth, was attained with 20 pounds actual nitrogen and 18 pounds P_2O_5 per acre. The response to the first increment of nitrogen and phosphorus applied was much greater than to the second.

In 1945 the interaction of nitrogen with phosphorus proved even more marked than in 1944, attaining statistical significance beyond

the .001 level. There was no response to nitrogen unless phosphorus was applied to the soil, and considering the level of precision of the experiment it is questionable if there was an actual response to phosphorus unless nitrogen was applied. Maximum growth, 1.78 centimeters diameter and 204.7 centimeters total shoot growth, was attained only at the highest levels of both nitrogen and phosphorus, although the gain over that obtained with 40 pounds of nitrogen per acre and 20 pounds of P_2O_5 is not statistically significant at the .05 level. As in 1944, the response to the first application of 20 pounds per acre of P_2O_5 was greater than to the second increment. However, increasing the nitrogen from 20 to 40 pounds per acre produced a greater growth response than in the 1944 test. In both seasons the growth where no fertilizer was used was less than half that attained with 40 pounds of nitrogen and 36 to 40 pounds of P_2O_5 per acre.

The evidence from the leaf analyses (Table II) supports that from

TABLE II—COMPOSITION OF LEAVES OF NURSERY TUNG TREES AS AFFECTED BY FERTILIZERS. MISSISSIPPI EXPERIMENTAL TUNG FARM — AUGUST 1944

Equivalent Fertilizer	Pounds Per Acre	Concentration of Corresponding Element in Leaves, Dry Basis			Statistical Significance of Gain (F Value*)
		Fertilizer Not Applied (Per Cent)	Fertilizer Applied (Per Cent)	Gain (In Percentage Points)	
N	40	2.23	2.62	0.39	4.89
P_2O_5	36	0.100	0.126	0.26	18.53
K_2O	30	0.97	1.02	0.05	2.49

*F required at 0.05, 2.57; at 0.01, 3.81; at 0.001, 5.88.

the growth measurement, in that leaves from trees that received the highest levels of nitrogen and phosphorus contained a substantially higher content of each of these elements than leaves from the trees at the lowest levels, but the application of potassium effected only a small gain in potassium content. Thus the application of 40 pounds actual nitrogen per acre increased the nitrogen content in the dry weight of leaf tissue from 2.23 per cent to 2.62 per cent. The 36 pounds of P_2O_5 per acre increased the phosphorus content from 0.100 per cent to 0.126 per cent. The significance of these gains is supported by statistical odds of 99:1 and 999:1, respectively. The application of 30 pounds of K_2O per acre increased the percentage of potassium in the dry leaf tissue only from 0.97 to 1.02, a gain supported by odds a trifle under 19:1. Under field conditions tung trees having about 1.00 per cent potassium in the leaves, dry basis, have made very satisfactory growth and a response to the small additional increment would not be expected. The fertilizers applied produced no important change in the concentration of calcium or of magnesium in the leaves.

The data on growth responses for 1942 are presented in Table III. The data show that, although either a side dressing of 8-8-6 fertilizer or an application of "colloidal" rock phosphate gave results superior to the check, poultry droppings proved to be by far the best single material, producing trees on the average 1.80 centimeters in diameter and 137.7 centimeters in height. The best combination, consisting of

TABLE III—RESPONSE OF TUNG SEEDLINGS TO POULTRY MANURE, PHOSPHATES AND COMPLETE FERTILIZERS MEASURED AT THE END OF ONE SEASON'S GROWTH. MISSISSIPPI EXPERIMENTAL TUNG FARM—1942

Treatment — Material (Pounds Per Acre)	Diameter (Cm)	Height (Cm)
Check	1.32	90.2
"Colloidal" rock phosphate,* 900 pounds	1.52	111.3
8-8-6 side dressing**, 225 pounds	1.57	115.6
Poultry droppings, 1,800 pounds	1.80	137.7
"Colloidal" rock phosphate, 900 pounds; 8-8-6 side dressing, 225 pounds	1.78	139.2
"Colloidal" rock phosphate, 900 pounds; poultry droppings, 1,800 pounds	1.91	140.2
8-8-6 side dressing, 225 pounds; poultry droppings, 1,800 pounds	1.98	154.4
"Colloidal" rock phosphate, 900 pounds; 8-8-6 side dressing, 225 pounds; poultry droppings, 1,800 pounds	2.01	147.8
Least difference significant at .05	0.140	13.9
Least difference significant at .01	0.186	18.4

*Contained 144 pounds P_2O_5, presumably as fluor apatite with some aluminum phosphate, costing $2.92 f.o.b. Florida shipping points.
**Contained 18 pounds P_2O_5 derived from superphosphate and costing about $1.00.

all three substances, produced trees averaging 2.01 centimeters in diameter and 147.8 centimeters in height, a statistically significant gain in diameter but scarcely worth the extra cost. The amount of poultry droppings used would supply only about 8 to 10 pounds of P_2O_5 per acre, which might be a limiting factor. When "colloidal" rock phosphate and 8-8-6 side dressing were combined, the growth obtained was substantially equal to that obtained with poultry droppings. To obtain further evidence on the value of the poultry droppings and of fortifying the side dressing of 8-8-6 with an application of "colloidal" rock phosphate in the row at planting time, plots with these treatments were randomized in each resplication of the factorial experiments of 1944 and 1945 previously described. The data are presented in Table IV. In 1944 the poultry droppings again gave good results but an additional increment of P_2O_5 above the 18 pounds per acre contained in the 8-8-6 was of no statistically significant ad-

TABLE IV—GROWTH RESPONSES OF TUNG SEEDLINGS TO APPLICATIONS OF POULTRY DROPPINGS, MINERAL FERTILIZER AND "COLLOIDAL" PHOSPHATE, MEASURED AT THE END OF ONE SEASON'S GROWTH. MISSISSIPPI EXPERIMENTAL TUNG FARM—1944 AND 1945

Material	P_2O_5 Applied			Plots	1944		1945	
	Pounds	Source	Cost		Diameter (Cm)	Shoot Growth (Cm)	Diameter (Cm)	Shoot Growth (Cm)
1,800 pounds poultry droppings	—	——	——	12	2.09	174.3	—	—
250 pounds 8-0-6	0	——	——	4	1.68	116.2	1.14	71.8
250 pounds 8-8-6	20	Super	$1.10	4	1.94	153.8	1.58	143.0
250 pounds 8-16-6	40	Super	2.20	4	1.91	166.0	1.60	153.5
250 pounds 8-0-6 plus 900 pounds "Colloidal" phosphate	144	Colloidal	2.92*	12	—	—	1.55	127.7
250 pounds 8-8-6 plus 900 pounds "Colloidal" phosphate	20 144	Super Colloidal	1.10 2.92*	12	1.82	136.2	—	—

*F.o.b. Florida shipping point, approximately $4.50 in southern Mississippi.
Differences of at least 0.20 centimeter in diameter or 40 centimeters in shoot growth are required for statistical significance at the .05 level, in comparing a reading for 4 plots with one for 12 plots. Owing to many factors involved it is impractical to give a complete table of least significant differences.

vantage, whether supplied in "colloidal" phosphate or as extra superphosphate in the 8–16–6. That the tung trees can utilize the raw rock phosphate is shown in 1945 by the gain of 0.41 centimeter in diameter and 55.9 centimeters in shoot growth when "colloidal" phosphate was added to 8–0–6. However, the 144 pounds of P_2O_5 in the "colloidal" phosphate, which, including freight, would cost about $4.50 in southern Mississippi, produced less actual growth than 20 pounds of P_2O_5 derived from superphosphate and costing $1.10. A smaller amount of "colloidal" phosphate might have sufficed, and since there is some residual effect one might not be justified in charging its whole cost against the first season, but in the absence of further information on these points, the superphosphate is to be preferred.

Summary and Conclusions

1. It is shown that under the conditions of these experiments, seedling tung trees in the nursery showed a marked response to the application of 20 pounds of nitrogen combined with 18 to 20 pounds of P_2O_5 per acre. However, some additional growth resulted from increasing the amounts to 40 pounds of nitrogen combined with 36 to 40 pounds of P_2O_5 per acre. When either nitrogen or phosphorus was applied in the absence of the other, growth increase was either entirely lacking or considerably less than was obtained by combining the two elements.

2. No response to potassium was observed. However, other observations indicate that on some soils potassium is required; hence, unless specific information for the particular site is available, it is wise to include it in fertilizer for tung nurseries as a matter of insurance.

3. Poultry droppings at the rate of 1800 pounds per acre applied in the row before planting are a very effective fertilizer for seedling tung trees in the nursery. A slight but not a profitable increase in growth was obtained by supplementing poultry droppings with (a) a side dressing of 225 pounds per acre of 8–8–6 mixed fertilizer, (b) 900 pounds of "colloidal" rock phosphate (16 per cent P_2O_5) placed in the furrow before planting the seed, or (c) with both side dressing and "colloidal" phosphate.

4. Seedling tung trees are able to utilize "colloidal" rock phosphate, but present evidence indicates that when cost is considered, superphosphate is preferred for fertilizing nursery tung trees.

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The Stub Graft as a Supplement to Budding in Nursery Practice

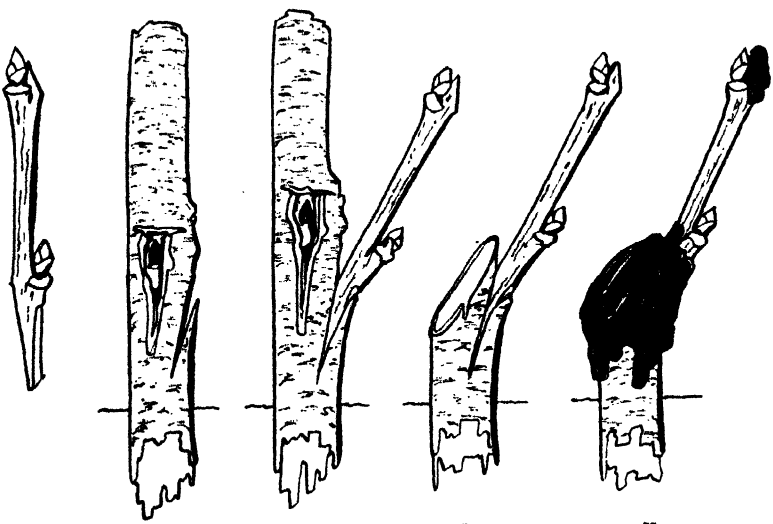
By W. H. UPSHALL, *Horticultural Experiment Station, Vineland Station, Ont.*

STUB grafting has been used extensively in top-working fruit trees, but apparently scarcely at all in nursery practice. In a letter to the author, Garner reports its use in an experimental way in the Station nursery at East Malling, England. Requiring no tie, this graft can be made quickly and needs no more after-care than budded plants. It may be a very useful supplement to budding. Where buds have failed, stub grafts may be used to increase the stand of 1-year trees. When rootstocks are scarce, or when there is a big demand for trees of a new variety or strain, the expense involved in grafting is amply justified.

Some nurserymen remove rootstocks on which the budding was unsuccessful; others bud these rootstocks in their second summer in the nursery. In both instances there is loss of time and money. By stub grafting it is possible to increase the stand and have trees of uniform age in the row.

TECHNIQUE

The technique of stub grafting in the nursery row is illustrated in Fig. 1.[1] Three years' work in the Station nursery at Vineland have shown that the following points should be observed:



A B C D E

FIG. 1. Method of stub grafting in the nursery. A — Prepared scion; B — Rootstock, in which a bud placed the previous summer had failed to grow, showing diagonal cut half-way through; C — Scion in place; D — Rootstock cut off as close as possible above the scion; E — The wounds covered with asphalt emulsion.

[1]The writer is indebted to Miss L. Heringa, Ontario Agricultural College, Guelph, for these drawings.

1. In Ontario the grafting should be done during April, preferably after the first cultivation and hoeing.
2. The scion should be dormant, or very nearly so.
3. A minimum rootstock caliper of 3/8 inch at point of grafting is required for sufficient tension to hold the scion tightly in place.
4. The slope of the scion should be in line with the row as a measure of protection against displacement in cultivation.
5. The cleft should be made half-way through the rootstock, preferably slightly below the wound caused in the budding operation.
6. The cleft should be made at a steep angle (Fig. 1B) so that the tilt of the scion may be kept to a minimum.
7. The scion should be as short as can be handled conveniently, 2 to 2½ inches.
8. The longest side of the wedge of the scion should be directly in line with the topmost bud so that after placement in the rootstock this bud will be in the inside position.
9. The cambium layers of scion and rootstock should be aligned along one side of the cleft. Usually because of the greater bark thickness of the rootstock, this means that the scions should be inset slightly.

Rootstocks which have already had their tops cut off above the inserted bud, now dead, may still be grafted, though it will be a little more difficult to open the cleft for insertion of the scion, especially with large rootstocks.

If more than one scion bud grows, the most desirable one with respect to growth and position may be saved, the others being removed with knife or pruners.

Results

The growth from stub grafts has been slightly less than that from buds, more particularly where the grafting was done late in the spring. The union has been satisfactory in all combinations tested but because of the unavoidable tilt of the scions there has been a slight crook in the trunk just above the point of union. If the scions are placed as near as possible to the upright position, and if the top bud

TABLE I—Results from Stub Grafting, Station Nursery, 1943 to 1945

Date	Scion	Rootstock	Number Grafted	Number Taken	Per Cent Taken
Apr 15, 1943....	Sweet Cherry	Mazzard	43	26	60
Apr 15, 1943....	Sweet Cherry	Mahaleb	21	9	43
Dec 3, 1943....	Sweet Cherry	Mahaleb	22	0	0
Mar 29, 1944...	Sweet Cherry	Mahaleb	21	9	43
Apr 29, 1944....	Sweet Cherry	Mahaleb	30	15	50
Mar 28, 1944....	Sour Cherry	Sour cherry seedlings	40	35	87
Mar 28, 1944....	Japanese plum	Myrobalan	12	10	83
Mar 14, 1945....	Sweet Cherry	Mahaleb	16	1	6
Apr 10, 1945....	Sweet Cherry	Mahaleb	25	14	56
May 19, 1945...	Sweet Cherry	Mahaleb	26	1	4
Mar 14, 1945....	Apple	Domestic Seedlings	15	10	67
Apr 16, 1945....	Apple	Domestic Seedlings	16	5	31
May 22, 1945...	Apple	Domestic Seedlings	16	12	75

of the scion is on the inside (Fig. 1C), the extent of the crook can be reduced to a point where few fruit growers would complain about it.

Insufficient work has been done to permit very definite recommendations regarding optimum time for grafting the various kinds of fruit. It appears however to be unwise to graft much before the time that the buds are bursting. This means that the scions should be collected some time previous to the grafting period, and should be held at or slightly above 32 degrees F to maintain their dormancy. If it is possible to have the nursery cultivated and hoed before the grafting is done so much the better, there being that much less chance of displacing the scions through accidental contact. In 1945 the May 19 grafting of cherry was almost a failure, but the May 22 grafting of apple was quite successful, though the growth of whip was less than that from scions placed earlier in the season. No explanation can be offered for the comparatively poor results from April 16, 1945 grafting of apple.

Investigations on the Occurrence, Transmission, Spread, and Effect of "White" Fruit Color in the Emperor Grape

By F. N. HARMON and ELMER SNYDER, *U. S. Department of Agriculture, Fresno, Calif.*

THE Emperor grape (*Vitis vinifera* L.) is the most important late shipping and storage variety grown in California. The total acreage in 1944 was 22,963 (1). The development of a satisfactory red color has been one of the major problems connected with the commercial production of this important grape variety. The range in color has been so great that the name "White" Emperor has been used to designate the poorly colored type to distinguish it from the normal "Red" Emperor. Varied proportions of these two types can be found in most Emperor plantings. The "White"-type vines are often found adjacent to the normal well-colored Emperor vines within the same vineyard. This variable color of the Emperor fruit has been noted over a period of years (2). The present investigations on the variable color of the Emperor grape were started in 1936 and have been continued through the 1945 season. While all phases of these investigations have not been completed, a summary is given of the work including the 1945 season.

PROCEDURE

The experimental procedures followed can be grouped under three main headings; namely, vineyard surveys, clone propagations, and tests by various grafting methods.

The vineyard surveys covered a wide range of Emperor plantings in 19 different commercial vineyards and experimental plots. Observations were made on vines ranging from 2 to 40 years of age, growing on various soil types, grafted on Phylloxera-resistant rootstocks, or growing on their own roots. Fruit color was mapped and foliage characters were studied in these 19 plots, aggregating 2,561 vines over the period from 1936–1945.

Clone propagations were made from selected vines to ascertain if the progenies developed fruit color true to the parent types. A total of 189 propagations were made from 22 selected vines. One-hundred ninety-nine vines originating from canes layered from adjacent vines were also mapped for color studies.

Seventy-two bearing vines producing white fruit in three vineyards were completely grafted using scions from selected "Red" vines. Some grafts were placed above and some below the union of the original scion variety with the rootstock. Sixty-two of such grafts have produced fruit. Fourteen additional "White" Emperor vines were top-worked so as to leave a part of the original vine growing along with the selected "Red" graft type. Fifty-six "Red" vines were graft-inoculated by using piece roots, chip buds, and green-bark tissue from "White" vines. Sixty-eight benchgrafts were made using a combination of the "White"-type selection as roots and the "Red"-type selection as scions.

Results of Vineyard Surveys

Early in these investigations, vineyard surveys indicated that there was a wide range in fruit color of the Emperor grape. This color difference was found in the same vineyard and even between adjacent vines, whether grafted on rootstocks or growing on their own roots, and irrespective of the age of vines. Two Emperor color types were very apparent, the normal "Red" type and a type ranging from no red color to a light pink which is designated as "White". In addition to these two types, another type was listed which appeared to be "Intermediate" and could not be classified in either the "Red" or "White"-type.

The "Red"-type could be distinguished by the early-autumn appearance of red color in the fruit, followed later by full red color, and by the green, relatively smooth foliage. In contrast, the "White"-type was noticeable because of the uncolored fruit on vines in the same vineyard with, and even adjacent to, "Red"-fruited vines. In the autumn the foliage of the "White"-type vines becomes increasingly yellowish-bronze and somewhat rugose in appearance. The type designated as "Intermediate", which was difficult to classify as either "Red" or "White", developed some color in the fruit in the more favorable seasons but produced some clusters with practically no color. This "Intermediate" type was less frequently found, and these investigations were chiefly concerned with the "Red" and "White"-types.

A summary of the vineyard surveys indicated that the Emperor vines could be divided into three classes based on the color of the fruit. Of the 2,561 vines mapped in the 19 plots, 59 per cent were classed as "Red", 32 per cent as "White", and 9 per cent as "Intermediate" in fruit color. The vines so classed have remained relatively stable with respect to fruit color during the period of surveys. Except for slight seasonal variations, 98.2 per cent of the vines have produced the same color type during the years of observation. There was considerable difference in the occurrence of the "White"-type in the different plots. Some plots had only a few vines of the "White"-type, in others it ranged from 10 to 35 per cent, while one plot of 20-year-old vines had 80.5 per cent of the "White"-type.

Sugar and acid determinations were made of the fruit of 100 "Red"-type and 95 "White"-type vines harvested each year at the same time and averaged for a 5-year period. The "Red"-type fruit averaged 19.8 per cent sugar (hand refractometer) and .55 acid (grams per 100 cc of juice, computed as tartaric acid), in comparison with 14.7 per cent sugar and .53 acid for the "White"-type fruit. In all tests, the "Red" fruit was consistently higher than the "White" fruit in sugar content while the acid content was not significantly different in the two types.

Results of Propagations

During the surveys, 199 vines originating from layered canes, with the layered canes still connecting them with the parent vines, were mapped for color studies. In each case the layered vine produced foliage and fruit characters similar to the parent vine. Of these 199 layered vines, 67.4 per cent were "Red", 23.1 per cent were "White", and

9.5 per cent were "Intermediate" in type. Vines propagated from cuttings taken from both "Red" and "White"-types have fruited for several years. Of 109 cutting propagations from 11 "Red" parent vines, 85.3 per cent produced "Red"-type fruit, 14.7 per cent were "White", and 1.8 per cent were "Intermediate". Some parent vines that gave some "White" progenies were producing "Red" fruit 8 years after the propagations were made. All parent vines could not be checked as some were eliminated when vineyard plots were pulled by growers. Of 80 cutting propagations from 11 "White" parent vines, 97.5 per cent produced "White" and 2.5 per cent produced "Red"-type fruit. While a high percentage of the cutting propagations have produced the parent type, some off-types were apparent.

Results of Graft Tests

To ascertain if the "White"-type vines could be grafted over with "Red"-type scions and produce "Red"-type fruit, 40 vines of the "White"-type in 2 commercial vineyards were grafted with selected "Red"-type scions. Some grafts were made above the original graft union with the Phylloxera-resistant rootstock and some below the original union of "White"-type and rootstock. Thus, the grafts made below the original graft union had no connection with the "White"-type other than the fact that the "White"-type had previously grown on these same rootstocks. Thirty of these grafts have been fruiting for several years and all have produced fruit of the "White"-type, even though, as stated above, selected "Red"-type scions were used.

In addition to grafts made in commercial vineyards, 32 "White"-type vines in an experimental plot were grafted with "Red"-type scions. Fourteen additional "White"-type vines were partially top-worked with "Red"-type scions allowing some of the "White"-type portion of the vines to continue growth. Even though "Red"-type scions of known parentage were used, the growth resulting from all these grafts produced "White"-type fruit and foliage typical of the "White"-type vines.

To further study the possibility of graft transmission of a color inhibiting factor, piece roots, chip buds, and green-bark tissue taken from "White"-type vines were grafted into 56 "Red"-type vines in the spring of 1944. Fourty-four "Red"-type vines were left as checks. During the 1944 fruit-ripening season, the graft-inoculated vines showed much reduction in fruit color in comparison with adjacent "Red" check vines, especially on the south portion of such vines, the side on which all graft inoculations were made. The sugar content of the fruit on these graft-inoculated vines was significantly reduced, as compared with the check vines. In the 1945 season, these same graft-inoculated vines, without further inoculations, produced only the "White"-type fruit and correspondingly lower sugar content, indicating that the effects of the graft inoculations had spread over the whole vine in a two year period.

"Red" scions have been benchgrafted on "White"-type cuttings and 68 of such grafts have been growing in vineyard form for 2 years. While no fruit has been produced, 67 of these grafts have typical

"White"-type foliage whlie only one graft produced the foliage normally expected from such "Red"-type scions.

Discussion

Vineyard surveys over a 10-year period have indicated a wide variation in color of Emperor fruit within the same vineyard and even on adjacent vines. The variable color occurred when vines were growing on their own roots as well as when grafted on Phylloxera-resistant rootstocks. This would indicate that rootstocks were not the cause of the variation in color. The "White"-type fruit has always been found to be lower in sugar content than the "Red"-type fruit. The leaves of the "White"-type take on a yellowish-bronze color early in the autumn and often much of this leaf tissue dies while the foliage of the "Red"-type remains green and relatively healthy, and this may account for the lower sugar and poorer color of the "White"-type vines. Ninety-eight and two-tenths per cent of all vines mapped for color studies produced the same color type during the 10 years of survey, thus indicating no rapid change in type or spread from vine to vine in the vineyard. Some vines classed as "Intermediate" cannot be explained at this time. In view of the evidence that a graft transmissable virus is present in the "White" -type vines, it is possible that such "Intermediate" -type vines may carry a strain less drastic in its effects.

While propagations by cuttings made from "Red" and "White" types did not always reproduce true to type, a high percentage, (85.3 per cent for the "Red" type and 97.5 per cent for the "White" type) did produce fruit similar to that of the parent type. It is thus evident that careful mapping and selection of the "Red"-type vines for propagation purposes should raise the general percentage of well-colored types in future Emperor vineyards. It would be preferable to mark such well-colored vines and watch them for several years to guard against the possibility of seasonal variations or the vines' being in the incubation stages of the disease.

"Red" scions grafted on "White" -type vines have produced only "White"-type fruit, with the exception of one benchgraft out of 68, which has produced the "Red"-type foliage. "Red"-type vines inoculated with piece-root, chipbud, and green-bark tissue grafts taken from "White-type vines have been greatly reduced in fruit color and sugar in one season, especially on those portions of the vines nearest to the grafts. During the second fruiting season, all of the fruit was similar to the "White" type. These results indicate that the "White" type does carry an infectious factor, possibly of a virus nature, which can be transmitted to well-colored Emperor vines, causing a change in foliage, a lower sugar content of the fruit, and a "White"-type of fruit. During the period of survey, extending over a 10-year period, no noticeable decrease in vigor or reduction in quantity of fruit production of the "White"-type vines could be observed.

Summary

A considerable number of vines in Emperor vineyards in California produce white colored fruit, low in sugar content as compared to the

normal red fruit. Records obtained over a 10-year period have indicated little change in the number of vines producing white fruit in mapped areas.

Fruit color of the Emperor grape variety can be stabilized by rigid selection of the "Red"-type vines for propagation. "White"-type vines cannot be made over by grafting such vines with "Red"-type scions, but should be removed and replaced with vines of the selected color type.

Graft tests indicate that the "White" type carries an infectious factor which may be transmitted to "Red"-type vines causing a change in type of foliage, a lower sugar content, and the production of "White"-type fruit, without noticeably decreasing vine vigor or quantity of fruit over a 10-year period.

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Drying of American-Type Grapes

By N. H. Loomis,[1] *U. S. Department of Agriculture, Meridian, Miss.*

The use of the American-type grapes for the production of raisins was suggested in 1943 as a possible means of supplementing the supply of raisins and increasing the amount of food, especially by the utilization of surplus home-grown fruit which otherwise would not be used. In spite of statements in the grape literature that American grapes are unadapted for raisins, limited experiments were conducted in 1943 and 1944 with a number of American-type grape varieties, to determine their suitability for drying, and the character of the dried product or raisins they would produce. Work was done at both the U. S. Horticultural Field Station, Meridian, Mississippi, and the Plant Industry Station, Beltsville, Maryland.

Materials and Methods

The many varieties of American grapes growing in the experimental vineyards in the two locations furnished a wide range of fruit types. Unless otherwise noted only fresh, fully matured fruit was used and it was considered to be mature when the seeds had lost their light color and changed to a uniform dark color.

The simplest method of drying consisted in spreading the fresh clusters of grapes on trays in a partially closed greenhouse where the temperature frequently reached 120 degrees F. Some fruit was also dried in a dehydrator at 120 degrees. Regardless of the method, the fruit was dried until no excess moisture could be squeezed from the berries. The rate of drying, even within the clusters, was not uniform. Some of the fruit dried more than desired, but, after removal from the drying chamber, took up moisture and became pliable again.

In an effort to reduce the drying time and to soften the skin of the fruit, the grapes were subjected to lye dips of varying concentration, temperature, and duration followed immediately by washing in cool water to stop the action of the lye and to remove it. A study was made on the effect of maturity of the fruit on the quality of the raisins, and numerous varieties were dried so as to determine their relative value for raisins.

Studies were also made of the drying or raisining of the muscadine grapes.

Results

The variety Champion was used in studying the effect of the duration, the concentration, and the temperature of the lye dip. The varieties Delaware and Lucile were used in studying the effect of the dipping treatments on the rate of drying. As the length of the dipping period was increased from 2 to 15 seconds, the softening of the skins increased. However, 5 seconds at 200 degrees F was about the maximum dipping period before the grapes acquired a cooked taste; and

[1]It is a pleasure to acknowledge the guidance and assistance of Dr. C. A. Magoon, who initiated this study.

this flavor increased as the duration of the dip increased. Also, after 5 seconds the pulp tended to expand and split the skin; and again the trouble increased with the duration of the dip. A ruptured fruit was worthless for raisins because the pulp separated from the skin and dried around the seeds within a hollow dry skin. After 15 seconds the skin was so tender that any handling of the fruit caused it to rupture and peel. The fruit dipped from 2 to 5 seconds dried satisfactorily and had an acceptable "raisin" flavor, whereas a longer dip impaired the flavor. The difference in the thickness of the skin was not so apparent after drying as before.

A boiling-water dip prolonged the drying time over that of undipped fruit, but all the lye dips reduced the drying time in comparison with no treatment. In a range of lye concentrations between ¼ and 4 per cent the quickest drying of the fruit following a 5-second dip at 200 degrees F was obtained with ½ per cent or more of lye. There was no apparent effect of the lye upon the quality of the raisins. Although both the hot-water and the hot lye dips altered the appearance of the undried skins, after drying they were not distinguishable in appearance or taste from the undipped fruits, provided the duration of the dip did not exceed 5 seconds or the lye concentration was not greater than 2 per cent. The skins appeared to be softened most at a dip temperature of 200 degrees F or more.

None of the dipping treatments caused a grape skin injury characterized by short shallow cracks called "checks", such as occurs when vinifera grapes are dipped. When these grapes are lye-dipped they remain in the solution until the skins become well checked and this injury is used as an index of the effectiveness of the treatment (1).

The varieties Barry, Brighton, Fredonia, Lindley, and Moore Early were harvested at different maturities. The first harvest was made about a week before the seeds darkened, the second harvest at maturity when the seeds had darkened, and the third about a week after full maturity. In all cases the best-quality raisins were obtained from the final harvest. They had more body, were sweeter and larger.

A list of the varieties raisined and their relative value is presented in Table I. Usually each variety was raisined in four ways; sundried and dehydrated, each with and without dipping. For this evaluation the best-flavored sample was used regardless of previous treatment. In general, the highest-quality grapes made the highest-quality raisins. Apparently quality of raisins is determined by the same esters that largely determine the quality of fresh grapes, and sugar content is of lesser importance.

In both 1943 and 1944 Seneca made the most palatable raisins of any variety tested, with texture similar to raisins made from vinifera grapes. They remained pliable, the skin was thin, the flavor very good, and the seed content low. This variety is of more than fifty per cent vinifera parentage. Varieties having a foxy flavor and aroma had an objectionable taste when raisined.

Muscadine grapes were dried without treatment, but considerable time was required and the dried grapes were extremely hard. With these as with the bunch grapes, it was thought that possibly lye dips

TABLE I—AN EVALUATION OF THE VARIETIES TESTED FOR RAISINS DURING 1943 AND 1944

Season of 1943		Season of 1944	
	Fairly Acceptable Raisins		
B*M**	Barry	BM	Barry
B	Brocton	B	Captivator
B	Captivator	B	C. A. Green
M	Delaware	M	Delaware
B	Diamond	B	Fredonia
B	Fredonia	B	Lindley
B	Golden Muscat	B	Moore Early
BM	Herbert	B	Norwood
B	Niagara	M	Salamander
M	Salamander	B	Seneca
B	Seneca		
B	Watkins		
	Quality Only Fair		
B	Brighton	B	Brighton
B	Campbell Early	B	Caywood 50
B	Cochee	B	Dunkirk
M	Extra	B	Emerald
B	Green Early	M	Extra
B	Hicks	B	Kentucky
B	Krause	B	Krause
M	Lukfata	M	Lukfata
B	Marjorie (Studley No. 2)	B	Montefiore
B	Moore Early	B	Niagara
B	Paragon	B	Peabody
B	Portland	B	Portland
B	Sunrise		
M	Wine King		
	Undesirable Raisins		
B	Arkansaw	B	Beta
M	Champion	M	Champanel
M	Eumelan	M	Champion
MB	Lucile	M	Lucile
		B	Manito
		B	Noah
		M	R. W. Munson

*B—Beltsville, Md., grown fruit
**M—Meridian, Miss., grown fruit

would reduce the drying time and soften the extremely tough skins so that the dried grapes would be more desirable. Therefore, lye dips of varying concentrations and duration were tried. A 5 per cent lye solution was about as strong as could be used without discoloring the skin and 15 seconds was the greatest duration of the dip without rupturing a considerable portion of the fruits. These treatments seemed to soften the skins of the fresh fruits materially, but after drying they were similar to the untreated grapes — hard and unpalatable. Even after exposure to high humidities they never became soft and pliable like commercial raisins.

The skin and pulp were separated in a few tests and the skins dried. The skin of a few of the highest-quality varieties makes very desirable muscadine pies and it appears that this treatment affords far more opportunity for this group of grapes than does preparation as raisins.

SUMMARY

Certain American-type grapes produced raisins suitable for home use. They were not so pliable or so meaty as the raisins from *vinifera* grapes, yet were wholesome and palatable.

Sun drying without any preliminary treatment was a satisfactory method of raisining the grapes, but dipping in a ½- to 2-per-cent lye solution at 200 to 212 degrees F for 5 seconds before drying shortened the drying time without altering the character of the raisins.

No treatment was found for making satisfactory raisins from the muscadine grapes, although no difficulty was experienced in drying them.

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Observations on Hybridizing Lowbush and Highbush Blueberries[1]

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THE cultivated blueberry industry has been developed principally with varieties of the northern highbush blueberry *(Vaccinium corymbosum)*. This species is found growing naturally in approximately the southern half of the Lower Peninsula of Michigan, while several species of the lowbush blueberry *(V. lamarkii)* are found in the northern half of the Lower Peninsula, and in many places in the Upper Peninsula.

Because of a scarcity of cash crops in the area, it would be economically desirable to grow cultivated blueberries in northern Michigan. However, the lowbush blueberry, because of its very low, trailing habit of growth, and small-sized berries, is not satisfactory as the basis for a commercial cultivated blueberry industry. Test plantings in northern Michigan of a number of varieties of the highbush blueberry have been generally unsuccessful, with the exception of one small area.

On the theory that crosses between superior selections of the lowbush blueberry and standard highbush varieties might yield hybrids of intermediate growth habit producing berries of larger size than those found on the lowbush blueberry, crosses were made in 1936, and at intervals since.

RESULTS

The results obtained from these crosses are shown in Table I.

TABLE I—INHERITANCE OF BUSH TYPE AND COLOR OF BERRY IN HYBRIDS OF LOWBUSH AND HIGHBUSH BLUEBERRIES

	Number Hybrids	Bush Type			Color of Berry		
		Low	Intermediate	High	Dark	Medium	Light
Rubel ×Lowbush 34*	17	17	—	—	13	2	—
Pioneer ×Lowbush 34*	22	21	1	—	15	7	—
Adams ×Lowbush 34*	12	12	—	—	5	5	—
Schigner 3 ×Lowbush 34*	13	11	2	—	10	3	—
Taylor ×Lowbush 34*	62	58	4	—	2	21	28
Concord ×Lowbush 3	2	2	—	—	2	—	—
Concord ×Lowbush 1	11	10	1	—	10	1	—
Pioneer ×Lowbush 1	3	2	—	1	—	3	—
Lowbush 1 ×Schigner 3	14	14	—	—	1	6	7
Lowbush 1 ×Rubel	19	19	—	—	19	—	—
Lowbush 1 ×Rancocas	6	6	—	—	6	—	—
Lowbush 3 ×Taylor	9	9	—	—	9	—	—
Lowbush 3 ×Pioneer	6	5	—	1	5	1	—
Lowbush 3 ×Rubel	17	17	—	—	17	—	—
Lowbush 3 ×Schigner 3	12	12	—	—	6	—	6
Lowbush 34 ×Schigner 3	7	7	—	—	—	—	7
Lowbush 34 ×Rancocas	4	4	—	—	4	—	—
Lowbush 35 ×Pioneer	3	3	—	—	3	—	—
Lowbush 35 ×Taylor	14	14	—	—	14	—	—
Lowbush 35 ×Schigner 3	4	4	—	—	1	—	3
Lowbush 1 ×Highbush 120	47	47	—	—	47	—	—
Totals	304	294	8	2	189	49	51

*A few plants were not producing fruit at the time of taking the records, which makes the number of seedlings listed for color of fruit incomplete.

[1]Journal article 812, New Series, Michigan State Agricultural Experiment Station.

Inheritance of Bush Type:—That the lowbush habit of growth is almost completely dominant is indicated by the fact that about 97 per cent of the hybrids were lowbush types. Out of a total of 304 hybrids, eight were intermediate in growth habit, and only two were distinctly highbush types. Six of the intermediate types had either Schigner 3 or Taylor as a parent. These are Native Michigan selections, supposedly of highbush origin. However, there is some question as to their being pure highbush types. There is a possibility that the other two intermediates and the two highbush types might have been the result of contaminations.

Inheritance of Fruit Color:—About 65 per cent of the hybrids produced berries of very dark blue color, and there were about 17 per cent each of medium and light blues. All of the light blues came when Taylor and Schigner 3 were used as one of the parents. As berries of light blue color are much preferred, these two parents and their hybrids are being extensively used in further breeding work.

Inheritance of Berry Size:—The inheritance of berry size is not shown in Table I, because none of the hybrids produced berries as large as the highbush parent. In fact, the berries produced by the hybrids were practically the same in size as those of the lowbush parent.

Discussion

Unfortunately, the undesirable characters of low growth habit, dark fruit color and small size of fruit, were dominant, or nearly so in the first generation of hybrids. Second generation hybrids are too young to permit accurate observations on the inheritance of these characters. It is apparent that finding suitable hybrids of lowbush and highbush blueberries is not going to be an easy task that can be accomplished in a comparatively short time.

Effect of Growth Regulating Sprays on Certain Blackberries in Oregon[1]

By George F. Waldo, *Department of Agriculture, Corvallis, Ore.*, and Elmer Hansen, *Oregon Agricultural Experiment Station, Corvallis, Ore.*

Fruit size is a factor of major importance in the berry industry. This is especially apparent when general attractiveness, ease of picking, and yield are considered. Because of these reasons, many otherwise desirable varieties are looked upon with disfavor by growers, processors, and consumers if fruit size characteristics are not satisfactory.

The size of berry may be influenced by the genetic constitution of the plant, the environmental conditions prevailing during the growing season, and by other factors. Marth and Meader (1) obtained a very marked increase in the size of blackberries grown in Maryland by spraying the blossoms with certain growth-regulating chemicals. Treatments similar to these have been applied to blackberries grown in Oregon and the results are reported herein.

Materials and Methods

Plant Materials:—Three selections of blackberries, U. S. No. 28, Oregon No. 266, and Oregon No. 731, which are being used for breeding purposes or are on trial for possible introductions as commercial varieties, were used.

U. S. No. 28 is a selected seedling from a cross of the Himalaya and the Oregon Evergreen. Oregon No. 266 is a selection from a cross of the Himalaya and the Eldorado, an upright growing blackberry. Oregon No. 731 is also a cross of the Himalaya with the Santiam (Ideal Wild) blackberry. The Santiam (Ideal Wild) is a selection of the native blackberry, *Rubus macropetalus*.

The plantings used were 4 years old and in good vigor. The rows were 200 feet or more in length and 8 feet apart. The plants were set 12 feet apart in the row. All were trained to a 2-wire trellis and the canes of each plant were trained separately.

1. 2,4–dichlorophenoxyacetic acid	20 ppm
2. 2,4–dichlorophenoxyacetic acid	40 ppm
3. 2,4–dichlorophenoxyacetic acid	80 ppm
4. Mixture of 4–chlorophenoxyacetic acid	40 ppm
and B-naphthoxyacetic acid	40 ppm
5. Ortho-chlorophenoxypropionic acid	40 ppm

The sprays were prepared by first dissolving the required amounts of the chemicals in Carbowax, then adding the mixture to 3 gallons of water. The solutions were applied by means of a 3-gallon compressed-

[1]Published with the approval of the Director of the Oregon Agricultural Experiment Station as Technical Paper No. 481. Contribution of the Department of Horticulture.

The writers are grateful to Dr. Paul C. Marth, United States Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering, for supplying the chemicals used in this investigation.

air hand sprayer. A single application was made in early June when the flower buds were partially or fully opened. The sprays were applied on a cloudy day and cloudy weather prevailed for several days following treatment.

Single plants were selected for each treatment and these were sprayed from both sides. Care was taken that the spray material reached every flower and flower bud. Plants on each side of the sprayed plant were left unsprayed. These were used as checks in the case of U. S. No. 28, while checks of the other selections were chosen from the unsprayed portions of the row, as these were longer rows than U. S. No. 28.

Method of Berry Sampling:—Berries were picked when fully ripe at intervals of 3 to 10 days depending upon weather conditions that affected the rate of ripening. One box (12-ounce) of berries was picked at random from each sprayed plant. One box was similarly picked from each of 3 different untreated plants.

Immediately after picking all berries were taken to the laboratory where they were weighed and counted. In addition, the volume was determined by displacement of water. These values, however, were found to agree closely with the weights and the results are therefore not reported.

Results

Effect on Plants and Flowers:—Marked epinasty developed on U. S. No. 28 within 3 days after spraying. Oregon No. 266 was affected to a lesser extent, while Oregon No. 731 showed no stem or leaf curvature. The affected plants recovered within a short period following treatment.

As the berries began to develop it became evident that the flowers in certain treatments had been injured. This was particularly noticeable where treatments 2 and 3 had been applied to U. S. No. 28, and to a lesser extent in Oregon No. 266. Some injury to flowers was observed on U. S. No. 28 from other treatments also. No injury to flowers of Oregon No. 731 was observed from any of the treatments.

Effects on Fruit:—Malformed berries were observed where there had been injury to the flowers. Where no injury to the flowers was apparent, the berries were generally larger due to the larger drupelets.

The average weight per 100 berries picked from the different plants at intervals during the ripening season are shown in Table I. The percentage increase or decrease due to treatment are shown in Table II and in Figs. 1, 2, 3.

The berries of the first picking of U. S. No. 28 from plants sprayed with solutions 2, 3, and 4 averaged 28 to 31 per cent greater in weight than the checks. The other treatments had no significant effects on the early ripening fruit. The later ripening berries from all treated plants generally tended to be smaller than the checks. In treatment 5 some of the pistils were injured by treatment, but the remainder were not stimulated in growth; hence the drupelets were similar in size to those from the check fruits but fewer in number. Treatments 2, 3, and 4 also injured the flowers, but the drupelets that developed were larger although fewer in number than in the checks.

TABLE I—WEIGHT (5 GRAMS) PER 100 BERRIES ON EACH PICKING DATE

Picking Dates	Treatment						Average of Checks
	No. 1	No. 2	No. 3	No. 4	No. 5	Average	
			U. S. No. 28				
Jul 31....	433	533	540	516	431	491	409
Aug 7....	365	417	412	452	370	403	434
Aug 10....	398	375	442	329	305	370	421
Aug 17....	361	—	357	335	335	352	399
Average	389	442	438	408	365	404	416
			Oregon No. 266				
Jul 20....	449	590	565	403	394	480	420
Jul 26....	419	553	502	383	383	448	344
Jul 31....	455	563	595	404	381	480	347
Aug 7.....	448	470	495	335	326	415	372
Aug 17....	450	351	—	408	391	400	479
Average	444	505	539	386	375	445	390
			Oregon No. 731				
Jul 16.....	250	305	294	263	280	278	209
Jul 23.....	235	278	281	241	256	258	194
Jul 26.....	198	240	238	218	222	223	182
Jul 30.....	186	226	232	211	206	212	179
Aug 7.....	138	172	154	176	141	156	155
Average	201	244	240	222	221	225	184

The berries of Oregon No. 266, which ripened in mid-season, showed the greatest effect from treatment. A maximum increase in weight of 31, 62, and 72 per cent resulted from treatments 1, 2, and 3, respectively. Plants treated with solutions 4 and 5 had larger berries in the second and third pickings, but were smaller than those of the checks at the beginning and end of the season.

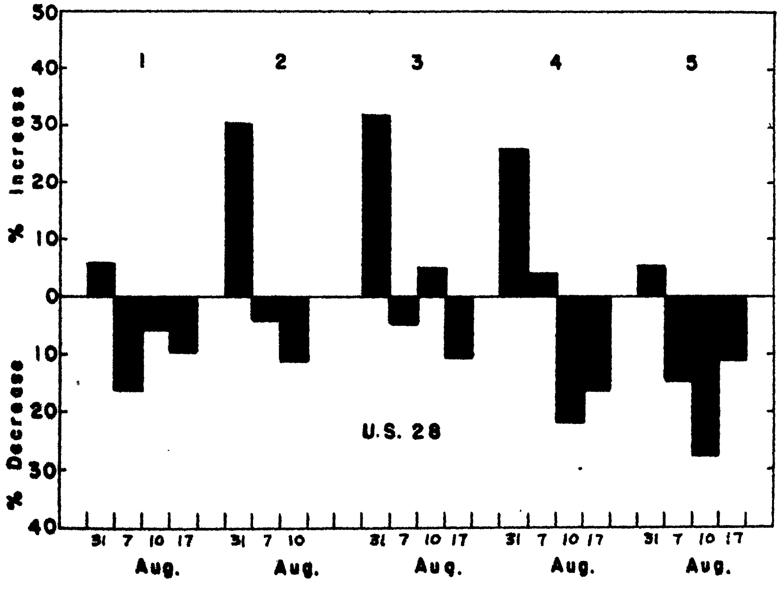

FIG. 1. Percentage increase or decrease in berry weight, in comparison with the check, in U. S. No. 28 blackberry. The data are for five treatments and three or four picking dates.

TABLE II—PERCENTAGE INCREASE OR DECREASE IN WEIGHT OF BERRIES IN COMPARISON WITH THE AVERAGE WEIGHT OF THE CHECKS

Picking Dates	Treatment					Average of all Treatments
	No. 1	No. 2	No. 3	No. 4	No. 5	
			U. S. No. 28			
Jul 31	+ 5.87	±30.32	+32.03	+26.16	+ 5.38	+19.95
Aug 7	−15.90	− 3.92	− 5.07	+ 4.15	−14.75	− 7.10
Aug 10	− 5.46	−10.93	+ 4.99	−21.85	−27.55	−12.16
Aug 17	− 9.52	——	−10.53	−16.04	−11.03	− 9.42
Average	− 6.25	+ 3.87	+ 5.35	− 1.89	−11.99	− 2.18
			Oregon No. 266			
Jul 20	+ 6.90	+40.48	+34.52	− 4.05	− 6.19	+14.33
Jul 26	+21.80	+60.75	+45.93	+11.34	+11.34	+30.23
Jul 31	+31.12	+62.25	+71.47	+16.43	+ 9.80	+38.21
Aug 7	+20.43	+26.34	+33.06	− 9.95	−12.36	+11.50
Aug 17	− 6.05	−26.72	——	−14.82	−22.51	−14.02
Average	+14.84	+32.62	+37.00	− 0.21	− 3.98	+16.05
			Oregon No. 731			
Jul 16	+19.62	+45.93	+40.67	+25.84	+33.97	+33.21
Jul 23	+21.13	+43.30	+44.84	+24.23	+31.96	+33.09
Jul 26	+ 8.79	+31.87	+30.77	+19.78	+21.98	+22.64
Jul 30	+ 3.91	+26.26	+29.61	+17.88	+15.08	+18.55
Aug 7	−10.97	+10.97	− 0.0	+13.55	− 9.03	− 0.90
Average	+ 8.50	+31.67	+29.18	+20.26	+18.79	+21.68

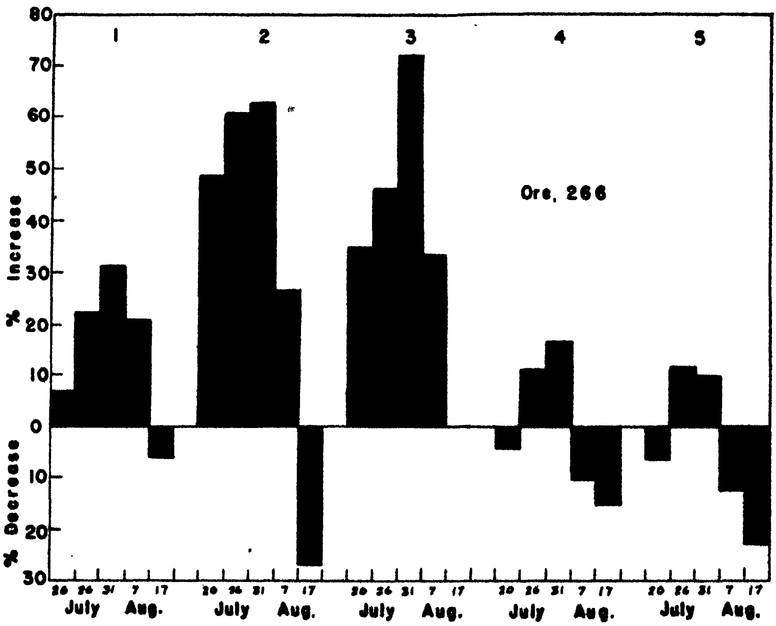

FIG. 2. Percentage increase or decrease in berry weight in comparison with the check, in Oregon No. 266 blackberry. The data are for five treatments and for four or five picking dates.

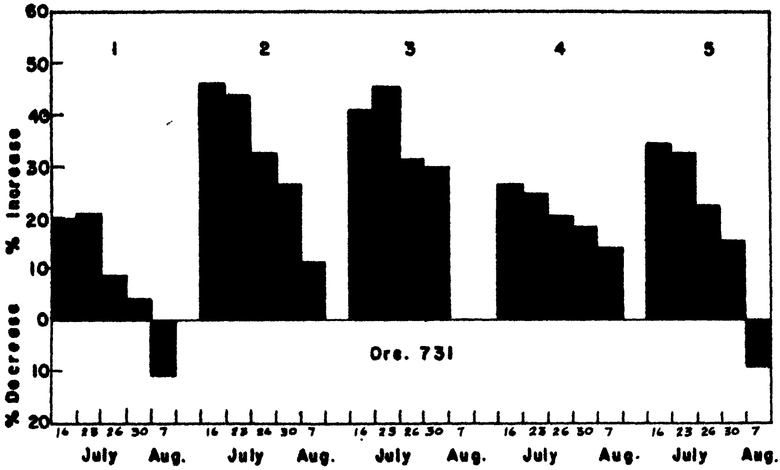

FIG. 3. Percentage increase or decrease in berry weight, in comparison with the check, in Oregon 731 blackberry. The data are for five treatments and four or five picking dates.

Oregon No. 731 appeared to be more responsive to all treatments and less susceptible to injury than the other two selections. All treatments resulted in significant increases in berry weight throughout the season, with the exception of the last picking from plants receiving treatments 1 and 5. The maximum percentage increases were 22, 46, 45, 26, and 34 for treatments 1, 2, 3, 4, and 5, respectively.

SUMMARY

Three trailing types of blackberries were sprayed with aqueous solutions of four different growth-regulating chemicals during the blooming period, and the effect upon berry size and weight throughout the harvest season determined. The data obtained indicate that differences in kind and degree of response among different varieties of blackberries may be expected from the use of growth-regulating chemicals.

2,4-dichlorophenoxyacetic acid (2,4-D) used in concentrations of 20, 40, and 80 ppm caused injury to flowers of U. S. No. 28 and Oregon No. 266, but not to Oregon No. 731. The size of drupelets was definitely increased by treatments with chemicals, especially when used at the higher concentrations. Ortho-chlorophenoxypropionic acid caused injury to flowers, but unlike 2,4-D did not increase berry size except on Oregon No. 731.

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Shredded Sphagnum vs. Peat and Sand as a Medium for Transplanted Blueberry Seedlings[1]

By W. H. Childs, *West Virginia Agricultural Experiment Station, Morgantown, W. Va.*

Investigators interested in the hybridization of blueberries have reported from time to time on the use of various rooting media for growing the seedlings. Soil, mixtures of sand and peat, forest litter, and mixtures of forest litter with soil and sand have all been tried at one time or another (2, 3). As far as the author has been able to ascertain, no one has reported on the use of sphagnum for this purpose, although blueberry seeds have been germinated on this medium and blueberry cuttings have been rooted in it (1, 2).

During the past 5 or 6 years investigators at the U.S.D.A. Plant Introduction Garden have published several papers on the use of shredded sphagnum as a seeding medium and also as a medium for growing seedlings of various plants (1, 4, 5, 6). Having seen some of the results obtained by these workers, the author was interested in comparing shredded sphagnum with peat and sand — the most commonly recommended medium for blueberry seedlings. Accordingly, a test was made to compare these two media.

Materials and Methods

The peat-sand mixture was made up of equal parts by volume of peat (pH 3.5) and sand, and the dried commercial sphagnum was rubbed through a screen containing 4 meshes to the inch. The plants were grown in the greenhouse in 2½ x 2½ x 3 inch wooden bands. For each cross used, the bands containing peat and sand were in one row, and those containing sphagnum in an adjoining row. The sphagnum was moistened, and both media were pressed firmly into the bands. The seedlings used were from cross-pollinations made in the spring of 1944. The seeds were germinated on peat moss during the fall and early winter and were pricked off in late February 1945, when they had from two to four leaves each. They were subjected to identical greenhouse conditions during the experiment. A nutrient solution, made by adding 1 pound of 5–10–5 fertilizer to 10 gallons of water, was applied to all plants at intervals of 2 to 3 weeks. Nineteen crosses were represented, with 28 individuals in one case, 10 in another, and 14 in all other cases for each medium. A few of these died shortly after they were transplanted, as indicated in Table I. The seedlings were grown in the greenhouse until September 5, 1945, when they were moved to the cold frame. Measurements of linear growth were made at that time.

Results and Conclusions

The results obtained are given in Table I. It is readily apparent that under the conditions of this study, shredded sphagnum was dis-

[1]Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 354.

TABLE I—GROWTH OF BLUEBERRY SEEDLINGS IN SHREDDED SPAGHNUM AND IN A PEAT-SAND MIXTURE

Cross*	Number of Seedlings Per Treatment	Average Linear Growth (Inches)		Increase in Favor of Sphagnum	
		Shredded Sphagnum	Peat and Sand	Inches	Per Cent
Rancocas ×4	26	68.8	48.1	20.7	43.0
141 ×Dixi	14	85.7	49.7	36.0	72.4
141 ×Atlantic	14	96.2	57.3	38.9	67.9
241 ×141	13	45.8	24.0	21.8	90.8
Atlantic ×Dixi	14	81.1	59.0	22.1	37.5
Atlantic ×241	14	99.9	70.4	29.5	41.9
Rubel ×Dixi	14	72.3	49.2	23.1	47.0
241 ×Atlantic	13	121.1	60.7	60.4	99.5
241 ×June	14	83.2	53.9	29.3	54.4
241 ×Cabot	14	92.9	62.4	30.5	48.9
241 ×Rancocas	12	106.0	48.0	58.0	120.8
241 ×Pioneer	14	100.6	39.3	61.3	156.0
2340 ×Atlantic	14	93.4	50.2	43.2	86.1
Rubel ×Rancocas	14	79.6	47.4	32.2	67.9
Jersey ×Atlantic	14	79.8	58.5	21.3	36.4
Jersey ×Stanley	14	76.3	45.6	30.7	67.3
Concord ×HC1401	13	108.4	58.8	49.6	84.4
Concord ×4	13	63.9	38.3	25.6	66.8
Atlantic ×HC1401	10	124.1	67.9	56.2	82.8
Entire group**	268	86.5	51.7	34.8	67.3

*The numbered parents are lowbush plants in the West Virginia selection planting.
**The figures given for the entire group are weighted averages derived from the original data.

tinctly superior to peat and sand as a medium for growing blueberry seedlings. The linear growth made in sphagnum ranged from 36.4 to 156.0 per cent greater than in peat and sand for the different hybrids, with an average of 67.3 per cent. These differences probably would have been still greater if weights could have been taken, since growths were not only longer but also of greater diameter in the sphagnum. Since these plants were part of a breeding experiment, however, they could not be destroyed, as would have been necessary to obtain weights.

Certain advantages and disadvantages in the use of sphagnum appeared in the course of the study. Sphagnum was somewhat more expensive than the peat-sand mixture as a rooting medium, and pricking off into this was slower and more difficult. In addition, shredding the sphagnum is a tedious and disagreeable task if no hammer mill is available. If the sphagnum is placed where it will dry out thoroughly, shredding is greatly facilitated. However, for experimental studies the advantages outweigh the disadvantages. Watering is easily done since it is almost impossible to overwater; the plants can be moved several times, even in wooden bands, without disturbing the root system; and the additional growth made is highly important in obtaining fruiting plants as quickly as possible.

SUMMARY

Five hundred and thirty-six blueberry seedlings representing 19 crosses were grown in wooden bands in the greenhouse at Morgantown, West Virginia, from February to September 1945. Half of these were grown in shredded sphagnum and the rest in a 1–1 peat-sand mixture. All plants received identical greenhouse care, including applications of nutrient solution at 2 to 3-week intervals. Shredded

sphagnum proved to be distinctly superior as a rooting medium under these conditions. The increase in linear growth over that made in peat and sand ranged from 36.4 per cent to 156.0 per cent for the various crosses, with an average increase of 67.3 per cent.

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Fermate for the Control of Mummy Berry of the Cultivated Blueberry[1]

By J. S. BAILEY and THOMAS SPROSTON, *Massachusetts State College, Amherst, Mass.*

ALTHOUGH mummy berry of blueberries is not a new disease, there is little in the literature about it. Wilcox (6) reported that the disease did more damage to cultivated blueberries in New Jersey in 1939, especially in the early blight stage, than in several previous years. "Experimental sprays of bordeaux mixture and of lime sulfur reduced, but did not control, the primary infection." "There was some indication that a dormant application of lime sulfur and arsenate of lead reduced the discharge of primary spores." Bailey *et al.* in 1941 (2) stated that mummy berry was the most serious disease of cultivated blueberries in Massachusetts and that spraying with a 5–5–50 bordeaux mixture at the beginning and again toward the end of the blooming period seemed to be effective.

This disease has been reported on *Vaccinium canadense, V. pennsylvanicum, V. corymbosum* (1), and *V. virgatum* (3) as well as on cultivated blueberries. "Only the fruit rot stage has been observed on *V. macrocarpon* Ait." (1).

The mummy berry disease is not serious every year. Occasionally, when weather conditions favor the build-up of the fungus, the disease becomes serious (3). Referring to lowbush blueberries in Maine (1), it is stated "A species of the fungus *Sclerotinia* causes a shoot blight that appears first in a monilial stage on leaves and progresses into the stems, frequently destroying them to the ground, and that also causes a hard rot of the fruits. The blight was so severe in 1929 that there were areas 4 or 5 feet in diameter in which all stems were destroyed."

Darrow *et al.* (3) in 1944 discuss briefly the life history of this disease and state "spraying has been ineffective against the mummy berry disease. The control method most common in New Jersey consists in sweeping or raking the soil surface under the bushes and frequent tillage between the rows during early spring when the spore-producing structures have started to form and before they have discharged their spores. The object of sweeping and tillage is to disturb the overwintering mummies at a critical period, thus stopping further apothecial development. An application of calcium cyanamide to the soil at the rate of 150 pounds or more per acre at the time of sweeping also seems to have been effective in rendering the mummies incapable of producing the spore-producing structures."

Several authors (1, 2, 3, 5) have referred to the fungus causing mummy berry as a species of *Sclerotinia.* The work of Honey (4) gives reason to believe that the genus should be *Monilinia.* The taxonomy and details of the fungus will be discussed in another paper.

Mummy berry had not been a problem in the planting of cultivated blueberries at Amherst until quite recently. During the 1944 season the disease was so prevalent that a severe outbreak could be anticipated

[1]Contribution No. 592 from the Massachusetts Agricultural Experiment Station.

in 1945. Therefore, it was decided to try Fermate since copper and sulfur sprays had not been successful in controlling this disease (3, 6).

The block used for the experiment was a variety planting consisting of 15 rows of 10 varieties. In most rows there were 60 to 65 bushes. A few rows had been thinned to half that number. Three plots were laid out across the rows so that each plot would include all varieties. The first plot, which included the first 10 bushes in each row, was sprayed four times. The second plot, including the next 10 bushes, was left unsprayed. The third plot, which included the rest of each row, was sprayed once at the time of the fourth spray.

It is important that the first spray application be timed according to apothecial development. Since published information on the subject is limited, a careful watch was kept for the appearance of apothecia. At Amherst the first appeared April 19. The first spray was applied the morning of the 20th. At this time the blueberry bushes were in the delayed dormant condition. The second spray was applied May 2 when most varieties had only a few blossoms open and leaves that were one-fifth to one-fourth grown. Cabot, a very early blooming variety, had one-third of its blossoms open. The third spray was applied May 22 when most varieties were in full bloom. The fourth spray was applied June 4 after most of the blossoms were gone. For all four sprays Fermate was used at the rate of 1½ pounds per 100 gallons.

Because the season was very rainy, a condition which favors infection (1, 3, 6), primary shoot and blossom infection was heavy at the time of the third spray, May 22. Therefore, counts of infected and uninfected shoots and blossom clusters were made on May 22–24, Table 1.

TABLE I—MUMMY BERRY. PERCENTAGE OF SHOOTS OR BLOSSOM CLUSTERS INFECTED IN SPRAYED AND UNSPRAYED PLOTS DURING 1945. THESE PERCENTAGES ARE BASED ON OBSERVATIONS ON ABOUT 600 SHOOTS OR BLOSSOM CLUSTERS ON THREE TO FIVE BUSHES PER PLOT PER VARIETY

Variety	Shoots		Blossom Clusters	
	Unsprayed	Sprayed	Unsprayed	Sprayed
Pemberton	0.3	0	3.4	2.2
Concord	3.2	2.4	3.6	0.3
Jersey	3.4	1.7	1.9	0.6
Rancocas	3.8	3.8	7.8	3.6
Rubel	6.7	1.7	1.4	0.6
Cabot	16.3	10.3	9.7	1.5
Scammell	21.0	15.4	10.5	9.6
Pioneer	26.0	19.3	8.3	2.4
Wareham	28.5	8.1	15.3	3.6
Stanley	39.0	20.1	2.5	0.9
All varieties	16.1	9.9	7.5	3.0

On July 6 and 7, as soon as diseased fruit could be distinguished from the healthy, fruit counts were made. These are given in Table II.

The weather during April, May, and June was ideal for the fungus and made disease control difficult. As shown by Table III and Fig. 1, rainfall was nearly twice normal. It rained on 26 out of the 49 days from April 17 to June 4. During the 23-day period of primary infection from April 19, when the first apothecia were found, until May 11, when the last was found, it rained on 13 days.

TABLE II—MUMMY BERRY. PERCENTAGE OF BERRIES INFECTED IN SPRAYED AND UNSPRAYED PLOTS DURING 1945. THESE PERCENTAGES ARE BASED ON OBSERVATIONS ON ABOUT 600 BERRIES ON THREE BUSHES PER PLOT PER VARIETY

Variety	Unsprayed	1 Spray	4 Sprays
Cabot	9.6	7.1	4.1
Rancocas	10.2	11.6	6.6
Concord	16.1	14.7	10.5
Scammell	21.0	19.4	10.3
All varieties	14.6	13.2	7.8

TABLE III—PRECIPITATION AND MEAN TEMPERATURE FOR APRIL, MAY, AND JUNE

Month	Precipitation (Inches)		Mean Temperature °F.	
	Normal	1945	Normal	1945
Apr.	3.35	5.43	45.7	51.8
May	3.60	6.45	57.1	54.1
Jun.	3.75	7.67	65.7	66.1
Total	10.70	19.55	—	—

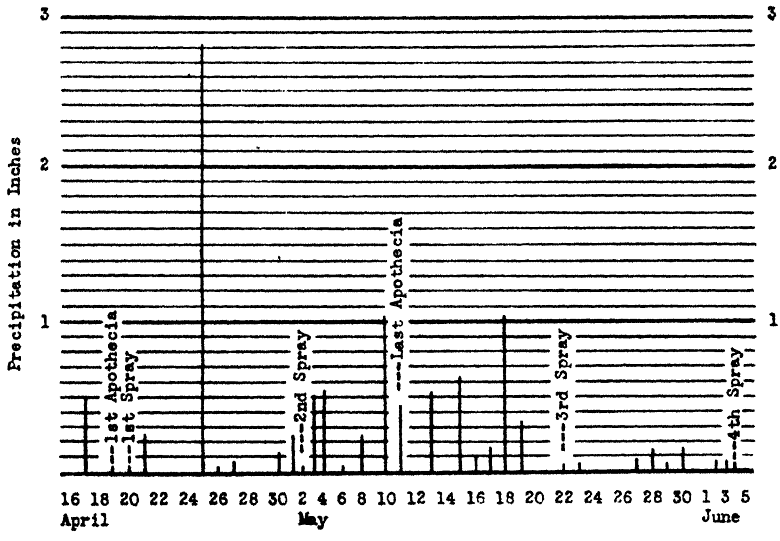

FIG. 1. Distribution of rain during the spraying period in 1945.

DISCUSSION

A study of the results shows several places where the spray program can be improved. Control would probably have been much better had the sprays been concentrated more in the early part of the season and timed better. The first spray would probably have been more effective if applied before the rain of April 17. The second spray should have been applied April 29 ahead of the rains of April 30, May 1, 2, 3, and 4. The third spray probably should have been applied May 7 ahead of the rainy period from May 10 to 19. The third spray as applied was not planned because previous work with other materials seemed

to indicate that a spray at the beginning and end of the blooming period would be sufficient. Because of the heavy shoot and blossom infection, the extremely wet season, and the length of the blooming period, it seemed worth while to risk upsetting pollination by spraying while the bushes were in full bloom. Since no yield differences which could be attributed to pollination trouble resulting from the spraying were observed, spraying with Fermate during bloom appears to be a safe procedure. The fourth spray applied at the end of the blossoming season as a single spray to part of the field was planned to see if, after heavy shoot and blossom infection, fruit infection could be prevented by one spray. The data in Table II indicate that this single spray was not effective. Since May was cooler and much more rainy than normal, it is probable that the primary infection period was longer than would be the case in a more nearly normal season.

In interpreting Table I it should be remembered that the counts were made directly after the third spray was applied. Therefore, the control obtained was due mostly to the first two and was influenced little, if any, by the third. General control of shoot and blossom infection was about 50 per cent. Since four sprays resulted in no better control on the fruit than the first two on the shoots and blossoms (Table II), it looks as if the early season sprays are the important ones.

As would be expected, there are varietal differences in susceptibility to the three types of infection. Scammell seems to be very susceptible to all three types, blossom, shoot, and fruit. Concord seems to have more fruit infection and less shoot and blossom infection. Rancocas has less shoot infection and more blossom and fruit infection. Stanley appears to have less blossom infection and more shoot infection.

There was no evidence of any injury to either fruit or leaves from the use of Fermate spray.

The data in Tables I and II were tested by analysis of variance. In Table I the differences between treatments and between varieties were significant both for shoots and blossoms. In Table II the differences between no sprays and four sprays, between one spray and four sprays, and between varieties were significant. The difference between no spray and one spray was not significant. Although control was not so good as desirable, the significant difference between treatments looks encouraging. Fermate appears to offer real possibilities for controlling the mummy berry disease.

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A Simple Method for the Preparation of 666

By JOHN W. SITES, *Ohio State University, Columbus, O.*

THE discovery of the insecticidal properties of the gamma isomer of hexachlorocychlohexane has stimulated considerable interest by horticulturists, especially since its use appears promising as a control for certain serious plant insects not controllable by D. D. T. Like D. D. T. this chemical has been known for a long time, but its insecticidal value is a comparatively recent discovery (1942). As a consequence of the war it has had very limited distribution even for research purpose, although it has been manufactured in England to some extent.

This brief report is presented merely to give a very simple method for its synthesis, in the event, investigators should wish to make the crude product for use in small amounts subject to its commercial availability. The gamma isomer has been demonstrated to have the most active insecticidal properties of the four isomers known to exist. In the crude product obtained from the described method a chemical determination of the percentage of the gamma isomer contained was not made, but from fly knockdown tests run it is logical to assume that varying amounts were contained in the different fractions.

METHOD AND RESULTS

To obtain crude 666, simple chlorination of benzene in the presence of sunlight is all that is required. A five pint bottle of commercial benzene, contained in a large water bath (the volume of the bath should be large enough to hold all the benzene in addition to the water to reduce the fire hazard in case the bottle should be broken) was placed on an electric hot plate which was insulated by an asbestos board so as to maintain the benzene at a constant temperature of 50 degrees C. A chlorine inlet, and outlet tube and a thermometer were placed in the benzene bottle. Chlorine was bubbled slowly from a small cylinder through a five pint trap bottle into the inlet tube which extended to the bottom of the benzene bottle. The outlet tube extended outdoors so that hydrochloric acid and any unreacted chlorine could escape. The apparatus was set up in an Ohio State University greenhouse and continued during periods of bright sunlight for 2½ days. The chlorinated benzene was then distilled until a dark brown liquid was present in the distilling flask. Upon standing over night fraction I crystalized out and was separated by filtration and dried. After further distillation and standing fraction II was obtained. Fraction III was obtained from the trap bottle into which some benzene had sucked back, and at the end of the reaction numerous white crystals were present. These were dissolved in benzene and obtained by distillation.

The melting points of the three fractions are contained in Table I.

Suspensions of the three fractions were made by mixing 10 grams of each crude fraction with 10 grams of clay, 20 drops of capryl alcohol and 200 ml of water and ground in a pebble mill for 24 hours. With these suspensions fly knockdown tests were made for each fraction and the results are given in Table II.

TABLE I—THE MELTING POINTS OF THREE FRACTIONS OF CRUDE 666 OBTAINED BY SIMPLE CHLORINATION OF BENZENE

	Melting Point (Degrees C)	
	First Crystal	Last Crystal
Fraction I	144	153
Fraction II	116	150
Fraction III	133	150

Fraction II, applied at the rate of 4 pounds per 100 gallons in a preliminary way gave good control of the aphis, Myzus persicae, infesting greenhouse calendulas, with no apparent injury to the plants.

TABLE II—THE TOXICITY OF THREE FRACTIONS OF CRUDE 666 AS DETERMINED BY FLY KNOCKDOWN TESTS *(Musca domestica)*

Per Cent Knockdown	Time (Minutes)	Concentration in Micrograms Per Sq. Cm.
	Fraction Number I	
50	195	1
80	258	1
	Fraction Number II	
50	117	1
80	135	1
50	73	2.5
80	95	2.5
50	30	10
80	36	10
	Fraction Number III	
50	91	1
80	113	1

DISCUSSION

From observations made by the writer a somewhat more efficient set up would probably result from placing the benzene in a train of smaller bottles and bubbling the chlorine from one to the other. From the results of the knockdown tests it seems probable that a product containing more of the gamma isomer would be obtained if this were run as a vapor phase reaction rather than as is suggested, but the apparatus required would be more extensive.

A Study of Cold Resistance of the Roots of the Latham Red Raspberry[1]

By W. G. Brierley and R. H. Landon, *University of Minnesota, St. Paul, Minn.*

Little attention has been given to the study of cold resistance in roots of the red raspberry. Carrick (1) reported in 1920 that roots of the Perfection, Loudon, and Cuthbert varieties, with soil removed and frozen under laboratory conditions, were injured at +17.6 degrees F, severely injured at +15.8 degrees F and killed at +14 degrees F. Under conditions of the experiment Cuthbert roots appeared to be slightly more cold resistant than those of the other varieties studied. Patterson (3) however, observed that these values could be questioned as raspberry plants could not survive in the Canadian prairie regions if their roots had been killed at such temperatures. In an accompanying table he showed that temperatures in the upper foot of soil at Saskatoon ranged from +10.4 to +0.6 degrees F during winter months, the low recording occurring in February. He suggested that survival under prairie conditions might be due to differences in the cold resistance of varieties. Introduction of reputedly hardy varieties such as Latham has directed attention to the present study of cold resistance of the roots. Roots of this variety have generally escaped injury in Minnesota when snow cover has been adequate.

In his study of winter soil temperatures at University Farm, St. Paul, during the exceptionally severe winter of 1935–36, Iverson (2) recorded minimum temperatures beneath 3 inches of snow of +7, +9, +11, and +13 degrees F at the soil surface and at depths of 2, 4, and 6 inches, respectively. For bare ground he reported the minimum at the surface as −7 degrees F, and −6, −5, −2, and 0 degrees F at depths of 2, 4, 6, and 8 inches, respectively. In some "open" winters, however, with no snow cover, there have been indications of injury to Latham roots. As information relating to cold resistance of Latham roots was lacking, a study of their behavior was begun in the spring of 1944.

Method

Selected nursery grown plants of No. 1 grade were planted in a good potting soil mixture in half bushel metal tubs. Five plants were set in each tub to insure development of a mass of roots. The tubbed plants were grown outdoors during the summer in a location where they could be given good care. At the end of the season cane growth averaged 3.5 feet.

Before the onset of severe cold weather, soil thermometers were inserted in the tubs so that the bulbs were in the center of the soil mass. Some of the tubs were left where they were exposed to outdoor temperatures until desired minimum soil temperatures were reached (Lots 1, 7, 8). As soon as the soil was frozen the remaining tubs were placed in a deep, covered frame where the soil temperature fell no lower than

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+18 degrees during the winter. One lot (Lot 2) was withdrawn from the covered frame and exposed for 36 hours in the low temperature laboratory, where air temperature was maintained at +4 ±1 degrees F. Soil temperature was held at +4 degrees for 10 hours. As lower temperatures could not be maintained with facilities available, other samples (Lots 3, 4, 5, 6) were placed outdoors from time to time in January or February when weather predictions indicated a probable night temperature aproaching the desired exposures. These tubs were placed in a shaded location to avoid rapid changes in soil temperature noted in tubs placed in the sun. In this manner the exposures shown in the figure and table were reached.

Freezing the roots in place in the soil simulated field conditions, insured a relatively slow fall in soil temperature, and avoided disturbing the roots until after the freezing treatments. Minimum temperatures were recorded in early morning. Differences between air and soil minima as shown in the table were attributed to the differing number of hours of air minima and a lag in soil temperatures near the point of equilibrium. Duration of soil minima was not over 6 hours in any case, except in Lot 2. After desired temperatures were reached in each lot the tubs were thawed slowly and brought into growth in a cool greenhouse where root condition and growth responses could be noted.

Results

Data obtained and illustration of growth responses are shown in the accompanying table and figure. This table shows the soil temperatures to which each lot was exposed, extent of browning in the roots, development of new roots and the performance of subsequent sucker growth. The accompanying figure shows the subsequent sucker growth in the greenhouse after a period of 7 weeks.

These data show that in Lot 1 there was no injury to Latham roots at +6 degrees F. In Lot 2 at +4 degrees there was no root injury, but the below ground tissues of "dormant suckers" were slightly injured as evidenced by slight browning. In Lot 3 at +2 degrees F this same type of injury was noted and the first indications of root injury appeared. This was only a light brown discoloration, however. Although

TABLE I — Cold Resistance of Roots of the Latham Red Raspberry, and Subsequent Growth Response of Treated Lots

Lot Number	1	2	3	4	5	6	7	8
Min. soil temp. (degrees F)	+6	+4	+2	0	−2	−4	−6	−9
Min. air temp. (degrees F)	+4	+4*	−5	−4	−8	−5	−9	−12
Browning in roots of 1944 or older	None	None	Light brown	Light brown	Light brown	Medm. brown	Dark brown	Dark brown
New root development	Many	Many	Many	Many	Many	Few	Few‡	None
Browning in tissues of 1944 "dormant suckers"†	None	Light brown	Light brown	Light brown	Medm. brown	Medm. brown	Dark brown	Dark brown
1945 suckers—from old roots	Many	Many	Few	None	Few	None	None	None
1945 suckers—from base of canes	Many	Many	Many	Many	Few	Few	Few	None
Growth of suckers—7 weeks	V. Vig.	V. Vig.	V. Vig.	V. Vig.	M. Vig.	M. Vig.	Very weak	None

*Controlled temperature in low temperature laboratory, +4 degrees (±1 degree) F for 10 hours.
†"Dormant suckers" developed from roots to soil surface only where bud was formed late in growing season of 1944.
‡New roots formed mostly at base of 1944 "dormant suckers". Very few formed on older roots.

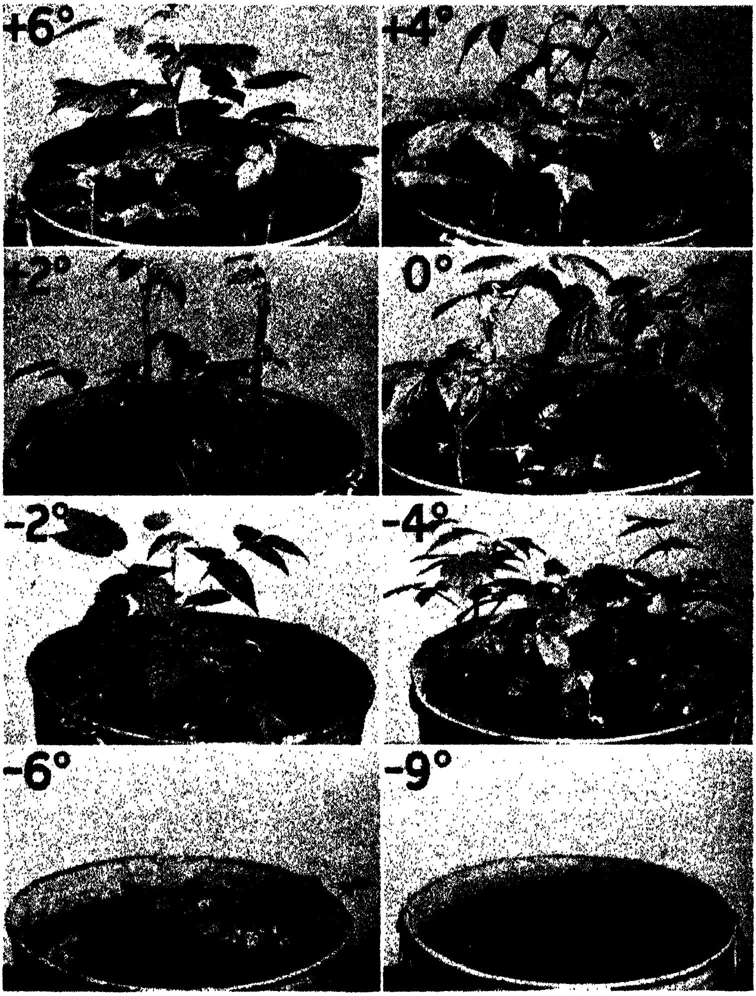

FIG. 1. Root injury as evidenced by growth response of Latham plants after exposure to low temperatures.
All established canes removed before photographing.

there were relatively few suckers developed on old roots after this exposure to +2 degrees those that grew were vigorous as shown in the figure. Injury in Lot 4 exposed to 0 degree was similar to that at +2 degrees except that no suckers developed from old roots. However, many very vigorous suckers arose from the below ground portions of the old canes.

After exposure to —2 degrees F (Lot 5) there was more injury to tissues of "dormant suckers" than at 0 degree but a few new suckers arose from old roots. Many new roots formed in this lot and in all

those exposed to temperatures higher than —2 degrees F. But only a few suckers developed on below ground portions of the old canes. The sucker of medium vigor shown for this temperature in the figure arose from an old root. This behavior and that of Lots 1 to 4 indicates absence of serious injury to roots at all exposures down to this point, but it was evident that this temperature could be considered close to the "danger point" for Latham roots.

Lot 6 after exposure to —4 degrees F showed an increase in injury. The older roots were medium brown, and few new roots developed. No new suckers arose from the older roots and few developed at the base of old canes. Suckers shown in the figure for this lot all were from the base of old canes removed before the pictures were taken. Injury was much more severe in Lot 7 exposed to —6 degrees F. All older roots were dark brown and very few new roots arose from them. The majority of roots that did appear arose toward the base of the "dormant suckers" that began growth in 1944. But all tissues of these "dormant suckers", except the cambium, were dark brown and they appeared to be dead at the point of attachment to the older roots. All these suckers were very weak and failed to make normal growth as shown in the figure. In Lot 8 exposed to —9 degrees F all old roots were dark brown, no new ones appeared and all "dormant suckers" were dead, indicating that the "killing-point" for Latham roots was somewhere between —6 and —9 degrees F under the conditions of this experiment.

Conclusions

From the results obtained under conditions prevailing in this study it is apparent that roots of the Latham red raspberry, when undisturbed in soil, are able to withstand much lower temperatures than those reported by Carrick for other varieties.

There was no severe injury at soil temperatures above —2 degrees F. Injury followed exposure to temperatures below —2 degrees F and the killing point appeared to be somewhere between —6 and —9 degrees F. These results indicate that under usual winter conditions in Minnesota severe injury or killing of roots of the Latham variety are not likely to occur.

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Ascorbic Acid Content of Strawberry Varieties and Selections at Geneva, New York in 1945[1]

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THE fruit breeding projects at Geneva have as one of their objectives the development of varieties with an increased ascorbic acid content. Strawberries have a higher ascorbic acid content than the other commonly grown temperate zone fruits. Reports of various investigators have shown a considerable range in the ascorbic acid content of different varieties (1, 2, 3, 4, 5, 6, 8). Because of this high ascorbic acid content and the differences between the few varieties so far reported it was decided to survey as much material as possible with the object of discovering varieties and selections to be used in this phase of the strawberry breeding project. It was also desired to learn whether certain crosses were superior to others in producing seedlings high in ascorbic acid. Accordingly in 1945 determinations were made of the ascorbic acid content of 308 varieties and selections from the breeding work of this station and other stations.

The effects of varietal, environmental, and seasonal factors have been studied by several investigators. Hansen and Waldo (3) have reported that color of ripe fruit, vigor of plant, and amount of leaf surface apparently have little influence on the ascorbic acid content of strawberries. They report that the strawberry leaves are extremely rich in the vitamin. Since shading the entire plant resulted in much greater reduction in the ascorbic acid of the berries than did shading the berries alone, it was concluded that the larger part of the ascorbic acid is formed in the leaves and translocated to the fruit. The vitamin potency appeared to be related to climatic conditions.

McCrory (5) has reported that strawberries shaded by leaves did not contain as much ascorbic acid as those exposed to the sun and observed that long-stemmed fruits were higher in ascorbic acid. The effect of sunlight was further demonstrated by higher ascorbic acid values for fruit harvested on sunny days. Everbearing strawberries had less ascorbic acid in the fall crop than in the June crop.

Olliver (6) has reported that ascorbic acid content increases during the development and ripening of the strawberry.

METHOD

The plants from which the fruits for analysis were taken were grown in the station variety test plat located on a light sandy loam soil and were growing in matted rows.

In view of the many factors that may cause variation in ascorbic acid content, careful sampling studies were made before the variety testing was initiated. In preliminary sampling of the variety Fairfax, it was found (see Table I) that small berries tended to have a higher concentration of vitamin c than large berries, and that mature, deep

[1]Journal Paper No. 673, New York State Agricultural Experiment Station, Geneva, N. Y.

TABLE I—SAMPLING TESTS ON STRAWBERRIES*

Samples	Mgm Ascorbic Acid Per 100 Grams Fruit	
	Test 1	Test 2
Large berries	62.8	51.8
Small berries	65.3	65.9
Mature berries	66.0	68.2
Immature berries	56.2	55.5
Transverse center slices	63.7	——
Tips and butts of same berries	62.7	——

*Variety Fairfax. Ten berries used for each test.

red berries were higher than the less mature, medium-red fruit. A transverse section through the center of the strawberry gave a sufficiently representative sample. A sample made up of 20 berries gave a mean value of 62.6 ± 1.8 mgs of ascorbic acid per 100 grams of fruit. The standard error seemed sufficiently small to warrant the use of a 20-berry sample whenever possible in variety testing, although it was realized that other varieties may be less uniform.

In testing each variety an effort was made to choose a random sample of well ripened fruit. As the transverse center sections were removed from the berries they were dropped immediately into 5 per cent metaphosphoric acid. The composite sample was homogenized in a Waring blender and ascorbic acid was determined by the indophenol-xylene extraction method (7). All analyses were completed within 24 hours from the time of harvest.

Ascorbic Acid Content of Strawberry Varieties

The ascorbic acid contents of the 37 varieties that were analyzed are shown in Table II. The variation is considerable, ranging from a high of 81 for Catskill to a low of 41 for Aberdeen with a mean of 62 mgs per 100 grams for the 37 varieties. The varieties Marshall, Maytime and Brightmore have higher readings in Oregon as reported by Hansen and Waldo (3). This may be due in part to a higher light intensity in that area. The majority of the widely grown varieties are relatively low in ascorbic acid content, *e. g.*, Blakemore, Klondike and Missionary with 42, 38 and 36 mgs per 100 grams of fruit respectively (8). At Geneva Howard, Dorsett, Marshall, Aberdeen, and Pathfinder were also relatively low in ascorbic acid. Of the widely grown varieties only Catskill is high in ascorbic acid, but the value for Fairfax is 62, the mean for the group. Even the varieties lowest in ascorbic acid compare very favorably with other commonly grown fruits.

Results with Strawberry Selections

The ascorbic acid content of 220 selections from the strawberry breeding plats at Geneva was determined and the results are shown in Table III. In Table IV the data are summarized for all selections involving one parent. The variation in the ascorbic acid content of the different selections is considerable. The high value of 98 mgs per 100 grams is well above that of 81 mgs per 100 grams for Catskill the highest of the varieties, but slightly lower than the 104 mgs per 100

TABLE II—ASCORBIC ACID CONTENT OF STRAWBERRY VARIETIES
GENEVA, 1945

Variety	Geneva 1945	Other Investigators
Catskill	81*	—
Vanrouge	77	—
Tenn. Shipper	75	—
Tenn. Beauty	75	—
Redwing	73	—
Daybreak	73	—
Dresden	72	—
Mastodon	71	64 (5)
Valentine	71	—
Robinson	70	—
Redheart	69	84 (4)
Camden	69	54 (4)
Sparkle	65	—
Suwanee	68	—
Gem	65	55 (5)
Midland	64	—
Temple	63	—
Fairfax	62	68(4) 55(8) 66(5)
Crimson Glow	62	—
E. Roosevelt	59	—
Massey	58	—
Paymaster	58	—
Maytime	57	72 (3)
Julymorn	57	—
Starbright	55	—
Brightmore	55	—
Pathfinder	55	49 (5)
Howard	54	56 (5)
Bliss	54	40 (4)
Tenn. Supreme	54	—
Boquet	53	63 (4)
Clermont	50	73 (4)
Dorsett	49	59 (4) 45 (8)
Culver	49	60 (4)
Marshall	49	78 (3)
Cato	45	—
Aberdeen	41	49 (5)

*Mg. per 100 grams of fresh fruit.

grams found in Beacon by Kirk and Tressler (4) in 1940. The low ascorbic acid content of 33 mgs per 100 grams is lower than the value of 41 mgs per 100 grams for Aberdeen, the lowest of the varieties. In several populations selections with ascorbic acid content substantially higher and lower than that of either parent have been obtained. The ascorbic acid content of Catskill is 26 points higher than that of its higher parent. In the larger populations greater opportunity exists for variation towards either extreme.

The variation between the means in most cases is not sufficient to indicate the superiority of one cross over another for producing seedlings high in ascorbic acid. In 8 of the larger populations with a total of 142 selections the means ranged from 58 to 66. For the same populations the high values ranged from 80 to 86. In 7 populations with a total of 122 selections the low values ranged from 39 to 46. The highest value of all, 98, was from the cross between Sparkle and Beacon, the latter variety being one of the highest in ascorbic acid. The limited evidence indicates that Beacon may be useful in breeding varieties high in ascorbic acid. Selections of Aberdeen, although only 12 in number, are low in ascorbic acid content with a mean of 55 and a high of 70.

Determinations of ascorbic acid content were also made for 44

TABLE III—Ascorbic Acid (Mgs per 100 Grams) of Strawberry Selections from Different Crosses

Ascorbic Acid Content of Parents				No. of Selections	Range		Mean	S.E.
					High	Low		
Fairfax	62	×Dresden	72	27	86	39	62	2
Fairfax	62	×Howard	54	3	62	42	53	–
Fairfax	62	×Clermont	50	1	—	—	79	–
Dresden	72	×Fairfax	62	26	81	42	62	2
Dresden	72	×Redheart	69	26	85	40	66	2
Dresden	72	×Sparkle	65	11	85	48	69	4
Dresden	72	×N. J. 303	66	6	74	64	69	–
Dersden	72	×Aberdeen	41	4	69	51	56	–
Dresden	72	×Northstar	—	2	76	58	67	–
Sparkle	65	×Dresden	72	20	80	55	65	1
Sparkle	65	×Howard	54	18	84	42	61	2
Sparkle	65	×Beacon	104 (4)	8	98	55	73	4
Sparkle	65	×Julymorn	57	6	79	51	63	–
Sparkle	65	×Vanrouge	77	1	—	—	76	–
Howard	54	×Fairfax	62	9	67	46	58	2
Howard	54	×Marshall	49	6	81	45	59	–
Howard	54	×Deutsch Evern	55 (6)	1	—	—	70	–
Vanrouge	77	×Dresden	72	10	82	55	68	3
Vanrouge	77	×Howard	54	5	79	51	63	–
N. J. 303	66	×Dresden	72	4	79	61	70	–
N. J. 303	66	×Northstar	—	2	65	54	60	–
Aberdeen	41	×Fairfax	62	3	56	51	54	–
Aberdeen	41	×U.S.D.A. 1021	—	3	64	43	51	–
Beacon	104 (4)	×Fairfax	62	4	81	71	75	–
Clermont	50	×Aberdeen	41	2	66	51	58	–
Clermont	50	×Redheart	69	1	—	—	58	–
Clermont	50	×Schauber	—	1	—	—	63	–
Clermont	50	×N. J. 303	66	1	—	—	67	–
Julymorn	57	×Vanrouge	77	1	—	—	75	–
Wyona	—	×Fairfax	62	1	—	—	51	–
Royal Sovereign	69 (6)	×N. Y. 9245	63	1	—	—	78	–
N. Y. 9214	—	×N. Y. 9565	—	2	61	50	55	–
N. Y. 6998	—	×N. Y. 7225	70	2	59	33	46	–
44 U.S.D.A. selections			—	44	83	40	65	–
9 N. J. selections			—	9	85	37	62	–

U. S. D. A. and 9 New Jersey selections. The means and the high and low values were in general agreement with those for the New York selections.

Until more extensive evidence is available involving larger populations from a series of crosses between varieties high in ascorbic acid and another series between varieties low in ascorbic acid definite suggestions as to the best breeding procedure may not be made. Since selections high in ascorbic acid occur in many populations the chemist who makes many determinations of any lot of seedlings and varieties is almost certain to uncover types high in ascorbic acid.

TABLE IV—Ascorbic Acid (Mgs per 100 Grams) of Strawberries from Different Parents

Variety Serving as One Parent	Abscorbic Acid Value of Parent Variety Mgs/100 Grams	Number of Selections	Highest Selection Ascorbic Acid Mgs/100 Grams	Lowest Selection Ascorbic Acid Mgs/100 Grams	Mean of All Selections Ascorbic Acid Mgs/Grams
Beacon	104	12	99	55	74
Dresden	73	109	85	40	66
Sparkle	66	67	99	42	68
Fairfax	62	72	86	42	61
Howard	55	42	84	42	61
Aberdeen	41	12	70	51	55

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Studies on the Control of the Blueberry Bud Mite (*Eriophyes vaccinii K.*)

By JOHN S. BAILEY and ARTHUR I. BOURNE, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

ABSTRACT

This paper will appear in full in the *Journal of Economic Entomology*, as Contribution No. 581 of the Massachusetts Agricultural Experiment Station.

THE blueberry bud mite, a serious pest of cultivated blueberries in North Carolina, was of little consequence in Amherst until a heavy infestation was found in part of a field in the spring of 1945.

The summer dinitro compound, DN–111, applied in June at the rate of 16 or 20 ounces per 100 gallons reduced the mite population from over 50 per bud to three or less. In spite of some spotting of fruit and foliage, the results look promising.

Some Relationships between Rest Period, Rate of Hardening, Loss of Cold Resistance and Winter Injury in the Latham Raspberry[1]

By W. G. BRIERLEY and R. H. LANDON, *University of Minnesota, St. Paul, Minn.*

WINTER injury to raspberry canes is an old problem. Chandler (6) and others have mentioned the puzzling nature of such injury. It has long been assumed that winter injury or relative hardiness in raspberries and other brambles differed between northerly and southerly regions, Bradford (2) stated that in the long growing season prevailing in Missouri canes become nearly mature in August and then resume growth later in the season thus becoming subject to injury. That the red raspberry responds to warm spells in winter more quickly than other fruits has been reported by Vaile (21) and others. Simonds (20) believed that alternate freezing and thawing did not break dormancy in raspberry canes as shown by lack of cambial activity in treated canes, but it is doubtful if cold has any appreciable effect upon such activity as Brierley (3) has shown that raspberry cambium does not become active until after development begins in the buds.

That the Latham variety is highly resistant to low temperatures has been known for at least 30 years. In 1916 Dorsey (9) stated that this variety (Minn. No. 4) ". . . was not injured by a temperature of 49 degrees below zero when left uncovered." In the severe winter of 1935–36 both Latham and Chief varieties grown at Grand Rapids, Minnesota, were uninjured by temperatures as low as —45 degrees F. Injury has occurred during mild winters, however, as indicated in a comment by Dorsey (10) relative to the winter of 1919–20. "The past winter was mild for all fruits except raspberries and strawberries." Brierley (4) also has reported widespread and severe injury to raspberries following warm spells in winter.

Frequent occurrence of winter injury to the reputedly hardy Latham raspberry in Minnesota has shown need for detailed study of this puzzling problem. At Duluth in late November and early December in 1939 and 1941, Latham buds began to swell during periods of mild weather. Bud scales separated and in some cases the buds burst and showed green at the tips. This behavior was followed by very severe injury and presented a serious problem to growers. Similar behavior has also been noted at times in other raspberry growing sections of the state. This out-of-season activity in the buds seemed to be directly related to occurrence of warm spells and apparently involved factors such as stage and duration of rest, ability to harden rapidly, and loss of cold resistance. Therefore, studies were undertaken to determine the role of these specific factors in winter survival. Results so far obtained are presented here.

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Method

Howard (17) concluded from his detailed studies that the rest period of woody plants may be tested by using twigs only. In these studies mature dormant canes have been cut in the field and carried through various time and temperature programs. After these treatments they have been kept for a few days in a cellar at 36 to 40 degrees F then placed in a cool greenhouse to record growth behavior. Butts of the canes were placed in water just deep enough to cover the slanting cuts. The water was changed every other day and fresh cuts made frequently to avoid plugging by bacteria or other organisms. The canes were sprayed frequently to lessen danger of drying.

In these studies cane samples have been exposed to very sudden and wide temperature changes. These treatments have been used in the belief that if canes survived they probably would have done so under less severe conditions in the field. Results so far obtained indicate that less severe treatments may prove useful as the studies progress.

Rest Period

Under conditions prevailing in Minnesota, and particularly in the Latham variety, the rest appears to be much "deeper" than Howard (16) reported for *Rubus idaeus* in Missouri. He showed that with the material used the buds became active in 9 days whether tested in late October or early January. Comments by Bradford (2) relative to late growth suggest that rest in raspberries under Missouri conditions is easily broken and may be completely over by late October. If this be the case, Howard (16) may have been observing behavior of canes after rest had ended. Bailey *et al.* (1) believed that the raspberry has a very short rest which ends even in hardy varieties by early December. With the Latham variety in Minnesota onset and duration of rest seem to vary somewhat with season and locality but deep rest usually is reached by mid-October, as shown in Fig. 1. With no exposure to cold Latham buds have required as much as 65 days to begin activity at that time.

Data for three seasons, shown in Fig. 1, indicate a gradual rather than a sudden break in the rest. Time required for bud activity in the greenhouse has shortened until in early December, following zero weather in the field, bud activity has begun in 7 or 8 days. Gradual breaking of rest may be due to the cumulative effect of the number of hours of exposure below about +41 degrees F, the temperature generally accepted as the threshold of hardening. Darrow (8), Magoon and Dix (18), and Chandler *et al.* (7) have shown this behavior in other plants and Fig. 1 indicates that the raspberry in Minnesota probably responds in the same way.

These data, and similar records not presented here, also suggest that time of development of deep rest varies with length of growing season, being earlier in long and later in short seasons. Records of the U. S. Department of Commerce Weather Bureau Station in Minneapolis show that from 1899 to 1938 the frost-free season averaged 171 days. At Duluth, where out-of-season bud activity has been noted, the

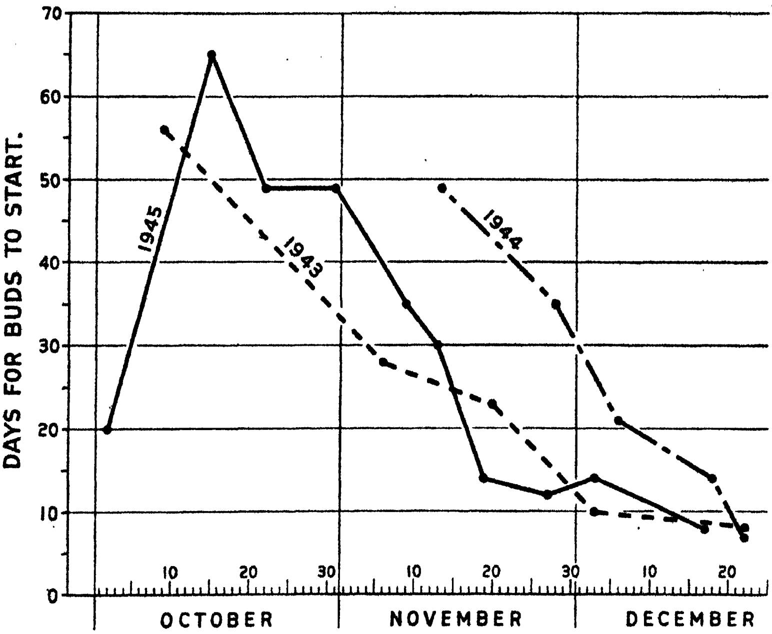

FIG. 1. Duration of rest period in the Latham raspberry in Minnesota. Curves show number of days in greenhouse for buds to start on canes collected on the dates shown during the season of 1943, 1944 and 1945.

frost-free season has averaged only 148 days. In 1945 the frost-free season in Minneapolis was unusually short, lasting only 119 days, although the actual growing season began before the late frost of June 2nd. Bud scales began to separate in 20 days on canes cut October 2 of that season (Fig. 1). This activity soon ceased, however, and there was no further development during the following 40 days. Such behavior indicates that rest was not fully developed in the field by October 2 in this very short season, that limited response to higher temperature occurred in the greenhouse, and that deep rest then developed to check further growth for 40 days. Deep rest was evidenced in the canes cut on October 15 as bud activity did not occur before 65 days in the greenhouse. It is of interest to note that renewal of growth in the first sample occurred after a total of 60 days in the greenhouse. Results obtained in the short season of 1945 closely resembled the pattern recorded in some seasons at Duluth where the growing season normally is short. Possibly the breaking of Latham buds at Duluth during warm spells late in November or early in December follows the breaking of rest in its early stages in October. In 28 of the past 70 years at Duluth the minimum temperature in October has varied between +20 and +8 degrees F. As early rest has been broken in the laboratory in early October by exposure to +20 degrees F, it seems likely that similar early breaking of rest may frequently occur in the field at Duluth.

These studies show conclusively that rest is broken earlier in the tip than in lower portions of the cane. Similar behavior has been reported by Bailey *et al.* (1). Buds in the basal portion have broken usually after those at the tip, and those in the central portion have been last to start.[2] As the tip portion of the cane represents growth occurring in August and early September in Minnesota, it actually is the product of a very short season. That rest is broken earlier in the tip region lends support to the belief that intensity and duration of rest in the cane as a whole are related to length of growing season, developing later in short seasons.

This early activity in the uppermost buds apparently has a direct relation to injury in the tip portion of the cane so commonly found in the field. Quite generally tip injury has been considered an effect of immaturity but it may be as much or more an effect of early bud activity during mild spells.

Fig. 1 shows that rest in Latham canes under Minnesota conditions is completely broken by early December. Dormancy then is retained only if temperatures remain, for the most part, somewhat below the threshold of growth. Brierley (4) has shown that Latham buds begin growth quickly at +45 degrees F. Grainger (11) found that the temperature of raspberry buds in sunlight is considerably above that of the air. Harvey (12, 13) found that brownish-red bark maintained the highest temperatures in winter sunlight, and that temperature of the bark may rise more than 18 degrees F in 10 minutes in sunlight. Well matured Latham canes in Minnesota vary in color but usually have brownish-red bark. These contributions indicate that raspberry canes and buds often may be subjected to temperatures well above that of the air during mild spells in winter. If bud activity is induced under such conditions, subsequent injury is to be expected. With these temperature responses in mind it is evident that factors needed in the make-up of a "hardy" raspberry variety are prolonged rest or deeper dormancy rather than an increase in the present high degree of ultimate cold resistance.

Rate of Development of Cold Resistance

Ability of woody fruit plants to harden rapidly apparently is a factor of major importance in the hardiness complex, but this factor has not received the attention it deserves. This type of behavior has been studied in the Latham variety during the past three seasons.

Results of preliminary studies in 1943 are shown in Table I. Samples of matured and dormant canes were cut in the field on the dates and after the temperature exposures shown in the table. Lots 1 and 2 were given additional exposure for 24 hours to +20 degrees F in the laboratory.

Examination of cane tissues and buds after a few days in the greenhouse showed no injury at the time of sampling except slight browning of the pith at bud bases in Lot 5 that had been exposed to several zero nights in the field. This behavior indicated that decline in temperature

[2]It should be noted that time of bud activity does not appear to be related to growth vigor.

TABLE I—Development of Cold Resistance in the Latham Raspberry. 1943

Lot	Date	Cold Exposure	Extent of Injury	
			Canes	Buds
1	Oct 9	Light frosts in field. 24 hours +20 degrees F	None	None
2	Nov 6	Variable in field. Minimum +14 degrees 24 hrs. 20 degrees F	None	None
3	Nov 20	14 frosty nights in field. Minimum +3 degrees F	None	None
4	Dec 3	Frosty nights, no zero	None	None
5	Dec 22	5 zero nights in field. Minimum -10 degrees F	None	Slight*

*Slight browning in pith at base of buds.

was accompanied by an increase in cold resistance. On October 9 enough resistance appeared to be developed in Lot 1 by light frosts to enable the canes to escape injury during 24 hours at +20 degrees F. Lot 2, exposed by November 6 to a minimum of +14 degrees F in the field and for 24 hours at +20 degrees F, also was uninjured. These results show that the Latham raspberry, like other woody plants in the north, hardens rapidly enough to escape injury from moderate cold in early fall. This effect has been reported by Harvey (14) who showed that short exposures at 32 degrees F promote hardening in tree seedlings even if most of the 24 hour period is warm.

Table I shows also that Latham canes hardened fairly rapidly in the 2-week interval between November 6 and November 20, thus enabling them to escape injury in the field at +3 degrees F on the latter date. Samples were not taken at sufficiently short intervals to note the time at which hardening was fully developed, but on December 22, after five zero nights, no injury had occurred in cane tissues of Lot 5, though the pith at the bud bases was slightly browned. Injury of this extent commonly occurs in the field but has little or no effect upon bud development, attachment of laterals to cane, or flowering and fruiting. However, when injury to bud bases is more severe and involves other tissues it is detrimental to all these growth expressions.

The data obtained in 1944 are shown in Table II. Only light frosts occurred during October and prior to November 7 the lowest recording was +25 degrees F. Lot 1 was collected on November 13 following

TABLE II—Development of Cold Resistance in the Latham Raspberry. 1944

Lot	Date	Cold Exposure	Extent of Injury	
			Canes	Buds
1	Nov 13	Several frosts early in Nov. Preceding week warm.	None	None
2	Nov 13	Several frosts early in Nov. Preceding week warm. 24 hours +20 degrees F.	None	None
3	Nov 13	Several frosts early in Nov. Preceding week warm. 24 hours -8 degrees F.	Killed	Severe*
4	Nov 28	Minimum in field +19 degrees F.	None	None
5	Nov 28	Minimum in field + 19 degrees F. 24 hours -8 degrees F.	Severe**	Slight†
6	Dec 18	Minimum in field 0 degrees F.	None	Slight†
7	Dec 22	Minimum in field -9 degrees F.	None	Slight†

*Severe injury to all tissues at base of buds. Upper part of buds not injured.
**Severe injury to phloem.
†Injury to pith at base of buds.

a week of warm weather with no frost at night. No cane or bud injury was noted at that time. Lot 2, collected on the same date and exposed for 24 hours to +20 degrees F also was uninjured, thus showing, as in 1943, (Table 1, Lots 1, 2) rapid development of resistance to moderate cold. In Lot 3, given the same treatment as Lot 2 plus 24 hours at −8 degrees F, the canes were killed and the buds severely injured. Apparently the cold resistance developed in the field and in 24 hours at +20 degrees F was insufficient to enable canes and buds to escape injury from sudden severe cold. In Lot 5, collected after several frosts and a minimum of +19 degrees F in the field, and then exposed for 24 hours to −8 degrees F, the phloem was dark brown but the buds were only slightly injured. These buds developed into shoots 2 to 3 inches long with fully unfolded leaves before dying. In Lot 6, collected on December 18 after a minimum of 0 degrees F, there was no injury to cane tissues and only slight discoloration of pith at the bud bases. Lot 7, collected after exposure to −9 degrees F appeared the same as Lot 6. In this season full resistance to cold was gained in the 20 days from November 28 to December 18.

Results obtained in the short season of 1945 are shown in Table III. Lot 2 shows that after two light frosts not enough cold resistance had developed for the canes to endure +20 degrees F. Lot 4, collected on October 15 after four light frosts, was not injured at +20 degrees F, but comparable material in Lot 5 was killed at −8 degrees F. Lot 7, collected on October 22 after a week of warm weather and a minimum of +28 degrees F, was uninjured by exposure for 24 hours to +20 degrees F. No injury appeared in Lot 8 following a minimum of +23 degrees F and none in Lot 9 after +14 degrees F in the field. These results again showed the ability of Latham canes to harden rapidly

TABLE III—DEVELOPMENT OF COLD RESISTANCE IN THE LATHAM RASPBERRY. 1945

Lot	Date	Cold Exposure	Extent of Injury	
			Canes	Buds
1	Oct 2	Minimum in field +32 degrees F.	None	None
2	Oct 2	48 hours +20 degrees F.	Killed	Killed
3	Oct 15	Four light frosts in field.	None	None
4	Oct 15	Four light frosts in field. 24 hours +20 degrees F.	None	None
5	Oct 15	Four light frosts in field. 24 hours −8 degrees F.	Killed	Killed
6	Oct 15	10 alternations* +37 degrees and +21 degrees F then 24 hours −8 degrees F.	Slight†	Slight††
7	Oct 22	Minimum +28 degrees after warm week. 24 hours 20 degrees F.	None	None
8	Oct 31	Minimum in field +23 degrees F.	None	None
9	Nov 9	Seven frosts. Minimum in field +14 degrees F.**	None	None
10	Nov 9	Seven frosts. Minimum in field +14 degrees. F. 24 hours −8 degrees F.	Severe	Slight††
11	Nov 13	Four nights below +25 degrees F. Minimum in field +11 degrees F.	None	None
12	Nov 13	Four nights below +25 degrees F. Minimum in field +11 degrees F. 24 hours −8 degrees F.	Slight†	Slight††
13	Nov 19	10 nights below +25 degrees F. Minimum in field +11 degrees F.	None	None
14	Nov 19	10 nights below +25 degrees F. Minimum in field +11 degrees F. 24 hours −8 degrees F.	None	None
15	Dec 10	Minimum in field −3 degrees F.	None	None

*8 hours 37 degrees; 16 hours 21 degrees F.
**7 frosts: 2 nights at 20 degrees F or lower.
†No injury in xylem, slight discoloration in phloem.
††Injury mostly in pith at base of bud.

enough to escape injury from moderate cold in the fall. Behavior of Lot 7 suggests that this degree of cold resistance may not be materially affected by a week of warm weather, at least at that time of year.

Behavior of Lot 10 indicated that cane tissues hardened sufficiently to escape injury at +20 degrees F could not endure sudden severe cold (—8 degrees F), although the buds showed only a slight discoloration which was mostly in the pith at the bud bases. In this case severe injury to cane tissues and only slight injury to buds showed, as in the previous season (Table II, Lots 3, 5), that Latham buds develop cold resistance more rapidly than cane tissues. In practically all lots showing this behavior the buds were able to develop into laterals with fully unfolded leaves, but these soon died. Similar behavior is not uncommon in the field. From evidence obtained in these studies it seems likely that such injury is caused by relatively early sudden cold before the canes have hardened completely, and before warm spells have caused the buds to become active. When warm spells result in early stages of activity, subsequent cold severely injures or kills buds. Injury from early cold does not appear to be a measure of ultimate cold resistance. When more is learned about varietal behavior it may be that some raspberry varieties now rated as lacking in ultimate cold resistance may more properly be classed as lacking ability to harden rapidly.

The behavior of Lots 11 and 12 shows that in four nights at minimum temperatures varying from +25 to +11 degrees F cold resistance developed rapidly enough to reduce injury at —8 degrees F from "severe" to "slight". Six days later, on November 19, cold resistance appeared fully developed as shown by lack of injury to Lot 14 exposed to —8 degreees F. Subsequent samples, such as Lot 15 and later ones, behaved in a similar manner. In this short frost-free season cold resistance was fully developed between November 9 and November 19.

Lot 6 is included in Table III to typify the behavior of a number of comparable samples collected on October 15. These canes were still in full leaf but terminal growth had ended about September 20. Behavior of Lot 4 showed that such canes were not injured at +20 degrees F. All these lots were exposed in the dark to alternate treatments of 8 hours at +37 degrees F and 16 hours at +21 degrees F. Samples were withdrawn after each treatment at +21 degrees F and exposed for 24 hours to —8 degrees F.

The first 2 lots so treated were killed at —8 degrees F, but three alternations developed a slight degree of resistance as shown by growth of buds on the lower half of the canes. These buds produced weak laterals which turned yellow and died in 6 weeks because the cane tissues were killed. Cold resistance in these lots increased until it was fairly well developed after 10 alternations. In this lot, shown as Lot 6 in Table III, there was no injury to the xylem, slight discoloration occurred in the phloem, and the pith at bud bases was browned. These canes lived for 12 weeks in the greenhouse and the uppermost laterals were in full bloom before the canes failed. Little if any additional cold resistance resulted from 13 alternations. Canes of

Lot 6 appeared about as well hardened as those in Lot 12, and more so than those in Lot 10 hardened under field conditions, but they were not quite as well hardened as those in Lot 14. This study showed that a fairly high degree of cold resistance could be developed in 10 days under controlled conditions thus furnishing additional evidence of the ability of Latham canes to harden rapidly. That the alternating treatments did not harden canes quite as well as in the field may have been due in part to sampling while the canes still were in full leaf and before accumulation of stored foods had ended. It may also be that development of cold resistance in the canes could not be completed in constant darkness as Moshkov (19) has shown that northern woody species harden best during short fall days thus suggesting that light may have a role in the hardening of woody as well as herbaceous plants.

Loss of Cold Resistance

Ability of a plant to develop a high degree of cold resistance admittedly is of great value in relation to winter survival. However, this value is materially reduced if such resistance is partially or wholly lost. Vaile (21) noted quick response of the raspberry to warm spells in winter. Brierley (4) reported severe injury to Latham canes under similar conditions and showed that tips of well matured and dormant canes were killed by sudden cold after only 2 days at 43 to 45 degrees F. Canes were killed two-thirds of their length after 4 warm days and completely killed by severe cold after 8 warm days.

As the temperatures used in the study mentioned above supposedly were at the threshold of growth the results did not indicate clearly whether injury was due to loss of cold resistance or to early stages of growth in the buds. Therefore a somewhat similar study was carried on in March, 1945, and January, 1946, to attempt to distinguish between loss of cold resistance and the breaking of dormancy. Matured and dormant canes were exposed for different lengths of time at +37.4 degrees F, a temperature believed to be below the threshold of growth. After the warm treatments all lots were exposed at −8 degrees F for 24 hours. Results of these tests are shown in Table IV.

In both seasons canes taken direct from the field and exposed to −8 degrees F were not injured. In these tests both cane tissues and buds were severely injured in Lots 2 and 6 after only two days at 37.4 degrees F, and cane tissues were killed in Lots 3 and 7 after 4 warm days. All buds were killed in 1945 (Lot 3) after 4 warm days. In 1946 buds were browned in both base and tip after 4 warm days. Following such injury growth developed from the sides of the principal buds between injured base and tip, or from accessory buds, and usually was weak and distorted in appearance.

These results show that the high degree of cold resistance in Latham is lost quickly during short periods of warm weather. Injury shown in Table IV was more severe than Brierley (4) reported for similar exposures at +43 to 45 degrees F. This difference may have been due to time of sampling in 1945 or to seasonal effect in 1946. Killing or severe injury to buds after exposure to +37.4 degrees F for 4 days

TABLE IV—LOSS OF COLD RESISTANCE IN HARDENED AND DORMANT LATHAM CANES FOLLOWING EXPOSURE TO 37.4 DEGREES F

Lot	Exposure to +37.4 Degrees F (Days)	Extent of Injury from Subsequent Exposure to −8 Degrees F	
		Cane Tissues	Buds
	March 9, 1945, Test		
1	0	None	None
2	2	Severe	Severe
3	4	Killed	Killed
4	8	Killed	Killed
	January 7, 1946, Test		
5	0	None	None
6	2	Severe	Severe
7	4	Killed	Severe
8	7	Killed	Severe
9	9	Killed	Severe
10	11	Killed	Severe

or longer makes it appear likely that activity in raspberry buds begins well below +43 degrees F, the accepted threshold for growth.

As these studies show that Latham canes quickly lose their cold resistance it is evident that winter covering with soil may avoid injury more by protecting the canes against warm weather than against cold.

As growth in the apical portion starts earlier than in lower portions of the cane it appeared possible that respiratory activity also might be greater there. A part of each of the lots shown in Table IV were used to compare respiratory rates. The data obtained were not consistent but in nearly all cases respiratory rate after 4 to 9 warm days was found to be highest in the apical portions. In March, 1945, respiratory activity in all portions of the cane was very much higher than in January, 1946. Brierley and Landon (5) found a sharp rise in the respiratory rate of dormant strawberry plants after April 1 before any other indication of growth could be detected. It may be that the dormant raspberry cane behaves in a similar fashion but results to date are not conclusive.

The number of hours of daily exposure to freezing temperatures needed to retain cold resistance in raspberry canes is not known. Harvey (15) showed that cabbage requires daily exposure at 0 degrees C for at least 1 hour to retain its cold resistance and similar behavior has been reported for other herbaceous plants. Although there are many contributions on the subject of hardening in woody plants apparently there are few if any that present data on the retention of cold resistance. In view of results obtained in these studies it seems likely that daily exposure to freezing temperatures may be as necessary for raspberry canes as for herbaceous plants. But injury produced by severe treatment in the laboratory does not show that injury in the field necessarily follows loss of ultimate cold resistance. Possibly not all resistance is lost during mild weather. If this be so, moderate cold following mild weather would not result in injury. Also, if the temperature falls gradually after a warm spell, cold

resistance may be regained. These possibilities need to be investigated before the puzzling problem of winter injury to raspberry canes may be fully understood.

Conclusions

These studies show that under Minnesota conditions deep rest of the Latham raspberry occurs in mid-October and is broken by early December. Declining temperatures that break the rest also cause rapid development of cold resistance. Severe injury occurring after mild spells shows that cold resistance is quickly lost. Evidence presented relative to rate of hardening and loss of cold resistance, and the conjecture relative to rehardening show need for recognition of several specific factors in the hardiness complex. If the term "hardiness" is used merely to indicate survival it lacks value. If "hardiness" means a high degree of cold resistance this factor has been present in the Latham raspberry for thirty years or more. It is apparent that objectives in breeding for "hardiness" in raspberries should include in addition to a high degree of ultimate cold resistance and ability to harden rapidly, factors such as (a) retention of cold resistance once attained, (b) longer rest or deeper dormancy in order to avoid out-of-season-bud activity, and (c) ability to reharden if initial cold resistance is lost.

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A Fruit Ladder Makes a Versatile Photographic Tripod

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INTRODUCTION

ORDINARY tripods are not very suitable for field or greenhouse photography. They are not adaptable to take close-up views of fruits on fruit trees, oblique views in greenhouses, or vertical photographs of fruit, vegetable, and grass plants from a height of 8 to 10 feet. A fruit ladder with certain modifications and the attachment of certain improvised pieces of equipment has been found to meet all of the above difficulties.

MATERIALS AND METHODS

A 10-foot fruit ladder was used as a tripod. Starting 4 feet above the ground, pairs of 5/16-inch holes were drilled in each side of the ladder midway between the successive rungs. The holes of each pair were 2½ inches apart and along a line making an angle of about 30 degrees with the front edge of the ladder side. (Fig. 2, near either foot of operator.)

A small movable shelf 7½ inches wide and 9½ inches long with a double brace 5½ inches wide and 7½ inches long (Fig. 1, near operator's knee), was made from 7/16-inch lumber. Two holes, each 5/16 inch in diameter, were drilled through the base of the brace so as to match the holes on the side of the ladder and have the top of the shelf in a horizontal position when the legs of the ladder are spread apart and the shelf bolted to the ladder. This movable shelf can be fastened to the side of the ladder by 3 x ¼-inch stove bolts with winged nuts. One 5/16-inch hole was drilled through the top of the shelf midway between the two sides and 5½ inches from the side of the ladder, for coupling on the box described below.

FIG. 1. Camera mounted two-thirds up the ladder in position to take oblique views.

A box was made from ½-inch lumber with two 5/16-inch holes, one at the center of the bottom and one at the center of the top. The top and bottom of this box were 9½ inches long and 6 inches wide, and the sides were 9½ inches long and 7 inches wide. One end was closed; the other was left open so that film holders and small camera accessories could be stored when "shooting" on location. This box can be turned in any direction horizontally.

A tilting top is fastened to the top of the box by means of a tripod-head screw. This permits pointing the camera in horizontal, oblique, and vertical directions.

Fig. 1 shows the camera with all attachments mounted two-thirds up the ladder and in position to take oblique views. This is very desirable in taking close-up views of fruit buds, flowers, and fruits in fruit trees. It is also in position to take oblique views of vegetable plots or vegetable gardens.

Fig. 2 shows the camera mounted vertically near the top of the ladder in position to take a photograph of emerging lima bean seedlings in flats on the ground. Grass plots, vegetable specimens, and fruit on the ground can be photographed to good advantage from this position.

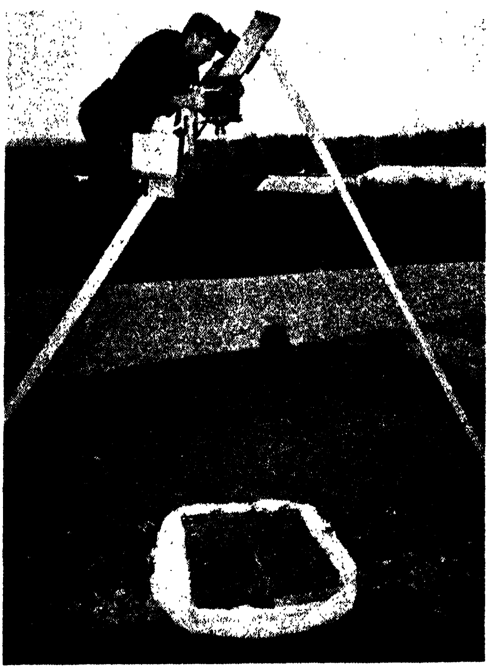

FIG. 2. Camera mounted vertically near the top of the ladder in position to take a photograph of emerging lima bean seedlings in flats on the ground.

Fig. 3 shows the camera mounted near the top of the ladder in an oblique position in a greenhouse. The ladder can be moved into position to take vertical views directly above a greenhouse bench.

Ball-and-socket tripod attachments have been found suitable for mounting a miniature camera on the side of the ladder, but present-day types of such attachments are too small and lack the rigidity required to hold a 4 x 5 or larger view camera.

CONCLUSIONS

A fruit ladder has been adapted for use as a tripod in taking field and greenhouse photographs. It has been found to be much more ver-

FIG. 3. Camera mounted near the top of the ladder in an oblique position in a greenhouse.

satile than ordinary tripods. Views, from high or low levels, can be taken from any position along the side of the fruit ladder by use of a shelf attachment, with horizontal, oblique, or vertical adjustment.

Simple Method for Rapid Drying of Soil Moisture Samples

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Several methods have been devised whereby soil moisture percentages may be determined very quickly. There are objectionable features to many of these methods, particularly when applied to certain conditions. The chief disadvantage of the standard oven-drying method when used for determining necessity for irrigation is the fact that by the time the samples are dry, several hours after being taken, the soil moisture percentage may have changed very radically. A method was devised, as a matter of necessity, whereby samples could be dried in 2 hours in an oven, with results of sufficient accuracy to determine when to irrigate.

Basically, the method depends on taking samples of nearly uniform amounts of soil and drying them in an oven at a fairly high temperature with a blast of air to speed up the process. By standardizing the sample cans and sizes of samples, very rapid calculations were possible so that within 3 hours from the time the samples were taken in the field, they were weighed, dried, and the calculations completed.

The required number of 4-ounce tin sample cans were weighed and all were brought to the weight of the lightest by grinding off small amounts from the edges of the covers or from the bottoms of the cans. A counterpoise of the same weight was also made for the use on the balance on which the weighing was done. Soil samples were taken from several parts of each plot for which a determination was wanted. Each lot was screened into a container and well mixed; from this a sample can was filled about half full. When all the samples had been collected from the different plots, the cans were taken to the laboratory and sufficient soil removed from each can so that exactly 20 grams of moist soil was left. With the lids off the cans, they were placed in the oven.

An electrically heated oven of small size was used and it was adjusted to maintain a temperature of 130 degrees C. At one side, a 4-inch electric fan forced air over the heating element and then over the open cans. Drying was very rapid and tests which were made showed that no further loss in weight occurred after 2 hours, and that most of the moisture was removed during the first hour. In other tests, in which a standard drying oven was used at temperatures of 130 degrees C for 2 hours, the results checked very closely with those obtained by drying over night at 105 degrees.

Because samples taken were all of 20-gram size, calculation of moisture percentages was very simple. When weighed on a balance, using the counterpoise, the difference between the dry weight and 20 represented the moisture loss. Losses can be computed in advance in a table or on a curve for all percentages. When a weight is obtained, it is only necessary to read off the corresponding percentage. No other calculations are involved. For most purposes, readings to 0.1 gram are sufficiently accurate, though if the balance is sufficiently sensitive, the weights may be taken to 0.01 gram.

Nutrient-Element Balance: A Fundamental[1] Concept in Plant Nutrition

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PRESENT fertilizer practice, based on the use of experimental plot technique as a means of determining the best fertilizer constituents and rate of application for a given crop, has many limitations which preclude general use of the results. These tests are generally limited to the study of the so-called "fertilizer elements," nitrogen, phosphorus, and potassium, without regard to other essential elements supplied in the fertilizer mixtures, such as calcium, magnesium, and sulfur, or to the non-essential elements such as sodium and chlorine. Lime is generally used only as a "soil amendment" and then only to varying degrees depending upon locality and custom. Furthermore, lime requirement is commonly based on soil reaction rather than on the calcium and magnesium requirements of the crop. Magnesium is generally ignored completely yet from the standpoint of its physiological significance and content in the leaves it is of great importance. In cases where plants show symptoms "typical" of the "deficiency" of specific essential elements, the "deficient" elements are generally also applied. When the nutrient-supplying power of the soil is considered, its determination is usually based on chemical tests for nitrogen, phosphorus, and potassium in soil extracts or in the plants grown in soil-sand mixtures without due consideration of the dilution effects and or the complex interactions which occur between the plant, the applied fertilizer elements, and those already in the soil.

The fundamental idea behind the use of leaf analysis as the means of determining the nutritional requirements of plants has been clearly stated by Lundegard (11). He points out that "leaf analysis is based on the functioning assimilating leaves as the central 'laboratories of nutrition'. The concentration of salts in leaves is regulated by the absorption power of the roots; and the growth of the whole plant, including the formation of seeds, is again controlled by the transformation of the nutrient salts proceeding in the green assimilating leaves." He further emphasizes that leaf analysis is an intergration of all circumstances which influence the availability of the salts in the soil.

Furthermore, leaf analysis offers the *only* means of applying the results of sand or solution culture experiments directly to field work, since the interpretation of nutritional status on the basis of leaf composition is not concerned with the means by which that composition was attained but only with the effect on growth of changes in leaf composition.

It is not the purpose of leaf analysis to replace field plot technique. The function of leaf analysis is to determine the direction and extent of nutrient unbalance within the plant.

Such analyses provide the knowledge whereby, under prevailing soil and cultural conditions, through fertilizer applications in suitably designed field experiments the materials to be used in obtaining the proper balance between elements can readily be determined.

The use of "deficiency" symptoms has long been recommended as a criterion of the fertilizer requirements of plants and the literature abounds with descriptions of symptoms "typical" of the "deficiency" of each of the essential nutrient elements. It has been the experience of the authors, both under field and greenhouse conditions, that there are no symptoms the cause of which can be accurately diagnosed visually. Though such a statement may at first appear to be unfounded, careful examination of the literature shows observations made by numerous investigators which substantiate the authors' experience. That magnesium "deficiency" may result from an excess accumulation of potassium in the leaves has been clearly demonstrated (1, 20, 22). It has been the writers' experience that the same effect may result from the accumulation of calcium and that calcium or magnesium accumulation or a combination of both may also produce potassium "deficiency." Further complications in the diagnosis of the cause of any visual symptoms are encountered in the similarity of symptoms resulting from different causes. Boynton and Burrell (1) have pointed out the similarity of magnesium and potassium "deficiency" symptoms in certain stages, and Wallace (21) has noted the similarity between potassium "deficiency" symptoms and those of chlorine toxicity. It is a matter of common knowledge that "iron deficiency" symptoms may be induced by excess carbonate. Excess of phosphate, copper, and zinc (3), or of manganese and cobalt (17), or too low a level of potassium, magnesium, or calcium in relation to either or both of the others (3), as well as a lack of available iron may also be responsible for symptoms of "iron deficiency." Numerous other examples could also be cited to illustrate the fact that symptoms are merely expressions of unbalanced nutrition, and even though the observer is able to determine by inspection of a most typical symptom the element causing a "deficiency," the unbalance responsible for the symptom could be ascertained only through the proper interpretation of total leaf analysis.

The contention that the correction of a symptom through the application of the suspected element is proof of an inadequate supply of that element is untenable. The elimination of visible symptoms does not necessarily indicate that the nutritional balance and intensity within the plant has been brought to the optimum for maximum growth and production (22).

Even were the preceding facts not true, the use of symptoms to determine fertilizer requirements would be impractical since the appearance of symptoms shows that a radically unbalanced nutrition has existed for some time and important economic loss has already occurred. Furthermore, the first and only infallible symptom of a deficiency of any element is evidenced by a reduced rate of growth and unless a more severe nutritive unbalance develops later that is the only symptom expressed.

For the past 6 years the authors have conducted factorially designed nutritional experiments on tung trees (*Aleurites fordii* Hemsl.) in sand culture. These experiments have involved the study of the effects on growth, symptom expression, and leaf composition of varying

levels and combinations of levels of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, chlorine, sodium, manganese, iron, zinc, and boron. Approximately 350 nutrient treatments have been employed, each treatment being applied to at least eight plants. Each experiment has involved from two to five elements at from three to five levels of supply. The experimental designs have been such as to permit the measurement of the direct effects on growth and leaf composition of variations in the supply of each element under study as well as to measure the interactions between the elements varied and those held constant. Leaf samples from all treatments have been analyzed for from 10 to 12 elements. In addition, data have been available on growth, symptoms, yield, and leaf composition from trees grown in numerous fertilizer experiments being carried on by co-workers in the field.

From the data obtained from these experiments with tung trees and from supporting data in the literature, the authors believe there is ample evidence to substantiate an expansion of the concept of nutrient-element balance.

It is hoped that this concept may serve not only to illustrate the fallacies in certain existing fertilizer practices, but also as a basis for the formulation of a practical and sound means of determining the mineral nutritional requirements of plants.

The concept that nutrient-element balance and intensity within the plant are the controlling factors in determining the growth responses and symptom expressions of plants has been stated in limited terms by Lagatu and Maume (9), and elaborated by Thomas (18) and by Thomas and Mack (19). As applied by these workers, however, the concept has in no case involved more than three elements at one time, being restricted to either nitrogen-potassium-phosphorus ratios or calcium-potassium-magnesium ratios. To the authors' knowledge the concept has not been further expanded, nor have the principles involved in its expansion to include other elements been defined.

PRINCIPLES INVOLVED IN THE CONCEPT

All other factors being constant, plant growth is a function of the two variables of nutrition, intensity and balance, as they are reflected in *the composition of leaves when the plants are in the same stages of growth or development.* At any given level of nutritional intensity (total equivalent concentration of all functional nutrient elements in the leaf) a multiplicity of ratios may exist between these elements. Maximum growth and yield occur only upon the coincidence of optimum intensity and balance.

As any element decreases or increases substantially from its concentration at optimum intensity, the maximum growth possible within the new limits of supply of that element can result only when the concentrations of all elements have been brought into balance at the new level of intensity determined by that element.

It is the authors' conviction that leaf composition is the only valid criterion of the nutritional status of the plant. The composition of leaves sampled with due consideration to time of sampling and position

of the leaves on the shoot represents a measure of all environmental factors, both external and internal, which have influenced nutrient accumulation by the plant. Gradients in the leaf content, varying with each element, occur during the growth and fruiting season, and from basal to terminal leaves, and also between fruiting and non-fruiting shoots. It is, therefore, essential that leaf samples be taken from modal shoots and from the same position on the shoots, and that a time of sampling be chosen when all shoots will be as nearly as possible at the same stage of physical development. The formation of terminal buds or the time of maturity of the crop are the most reliable indications of similarity in the stages of development. The determination of the nutritional requirements of plants based on foliar analysis can be accomplished, however, only with as complete a knowledge as it is possible to obtain regarding the factors affecting the accumulation of nutrients in the leaves.

Many of these factors, including their modes of operation and interactions, have been determined and studied by the authors. It is intended to discuss in this paper, however, primarily the end result of the interactions of all of these factors, that is, the mineral composition of the leaves and the relationship of that composition to the growth and yield of the plant.

As previously stated, at any level of nutritional intensity there exists a nutritional balance at which "optimum" growth for that intensity level will result. This means that at any given level of nutritional intensity, provided all nutrient elements are in proper balance, it is possible to obtain plants that appear normal in every respect and in which all metabolic processes are probably qualitatively normal. Maximum growth and yield, however, result only when the proper balance of nutrient elements occurs in combination with their optimum intensity. It is thus possible to have plants lacking any distinctive symptoms of malnutrition yet varying over a wide range in growth, or yield, or both.

It is also possible to have plants growing at a high intensity of nutrition, which, in the absence of more vigorous or higher yielders for comparison, may appear to be making maximum growth and yield yet be capable of greater yields were a more favorable balance brought about through proper fertilizing practices.

Under conditions of optimum balance, whether nutritional intensity is high or low, any critical change in the accumulation of one or more elements not accompanied by appropriate changes in all of the other nutrient elements will result in an unbalanced nutrition which will be reflected first in decreased growth and later, if the unbalance is intensified, in additional reduction in growth or yields or in the appearance of leaf symptoms or in all three ways. This has been particularly well illustrated by Walsh and Clarke (22) in their work on potassium-induced magnesium deficiency of tomatoes. Conditions of excessive potassium fertilization resulted in depressed growth and yield together with symptoms typical of magnesium "deficiency," the severity of the disorder depending upon the degree of unbalance between the concentrations of potassium and magnesium in the leaves. Their

growth and yield data further corroborate these authors' experience regarding the impracticability of the use of symptoms as criteria of fertilizer requirements. They point out that, though the application of magnesium may correct the symptoms of magnesium "deficiency" resulting from excess potassium, reduced growth and yield also result from such a procedure (probably due to bringing about an unbalance between both potassium and magnesium in relation to other elements). They emphasize that the only satisfactory means of bringing about optimum growth and yield is through reduction of the available potassium in the soil by continued cropping.

Similar relationships in the balance of all three of the bases, calcium, magnesium, and potassium, brought out in our work have already been mentioned.

Further analogous relationships between the so-called "minor elements" as well as between the "major elements" and the "minor elements" are discussed later in this paper and will serve to further illustrate the fact that instead of the term "deficiency," the term "toxicity" might be equally appropriate in referring to any particular symptom of malnutrition. In fact the determination through foliar analysis of the particular unbalance responsible for a symptom might make the term "toxicity" more appropriate, as by this procedure it is possible to determine, for example, whether potassium "deficiency" is due to a toxic level of calcium or of magnesium or of both. As the unbalance is more apt to involve a number of elements rather than only two, we prefer to define the disorder in terms of the particular unbalance which has been determined through leaf analysis to be responsible.

Consideration of the number of elements whose availability in the soil permits their possible accumulation in the plant and the possible interactions which may take place between them, both as regards accumulation by the plant and functional concentration within the plant, has caused some workers to disparge the possibility of obtaining knowledge adequate to permit practical interpretation of foliar analyses in terms of fertilizer requirements.

We thoroughly recognize the complexity of the problem but believe, as has been stated by Chapman (3), that ". . . . the development of reliable methods is a matter of carrying out sufficient experimental work to establish proper standards, and to determine the significance of departures from these standards in terms of yield and quality of plant product."

The importance of considering the functional concentration of *all* mineral elements in the leaves cannot be overemphasized. Merely because an element has not been determined to be essential for normal plant growth does not mean that its accumulation in the leaves may not influence the accumulation or function of one or more essential elements. It has been shown, for example, that aluminum may exert a competitive effect on copper and when absence of aluminum is approximated copper may become toxic (10).

Richards (16) has expressed the opinion that soduim, though not essential to plant growth, may depress the accumulation of other ele-

ments and thus improve the general condition of the plant. Inspection by the authors of certain data in the literature relating to sodium nutrition has led them to the opinion that one of the principal effects of sodium in sodium-accumulating plants results from its differential depressing effects on other bases (greater depression of calcium and magnesium than of postassium accumulation). Thus at times sodium accumulation may bring about a more favorable calcium-magnesium-potassium ratio in the plant in which case beneficial effects result from its accumulation, and under other conditions, sodium may result in a less favorable ratio between these elements when a detrimental effect results. Other competitive effects between essential and non-essential elements might also be mentiond such as those between sulfur and chlorine (6) and between sulfur and selenium (8).

Because of the fact that the cation : anion ratio within the leaf is a constant (15, 12), it is evident that at a given concentration of anions any increased accumulation of one or more cations must be accompanied by an equivalent decrease in one or more of the other cations. Conversely, at a given concentration of cations any increased accumulation of one or more anions must be accompanied by an equivalent decrease in one or more of the other anions. Variations in the accumulation of cations or anions, however, influence not only the accumulation of other ions of the same charge but may either increase or decrease the accumulation of oppositely charged ions. Therefore, though the cation: anion ratio remains a constant, the absolute level of both may be either increased or decreased by conditions which promote the accumulation of one or more ions of either charge. For this reason, an increased or decreased accumulation of one ion may not always be accompanied by an equivalent decrease or increase in the accumulation of one or more similarly charged ions. It should be pointed out that the terms cations and anions as used here refer to all ions both inorganic and organic, whether dissociated or undissociated. It is also important to remember that present techniques do not permit the determination of the actual total of either the anions or cations in leaf tissue, nor is it possible to determine by analytical procedures whether certain mineral nutrients occur in anionic or cationic form in the plant.

In the authors' experiments, increased magnesium or potassium accumulation brought about by an increased available supply of either has generally resulted in a decrease in the total accumulation of calcium + magnesium + potassium. Increasing calcium accumulation, however, has generally resulted in an increased total equivalent accumulation of calcium + magnesium + potassium.

Balance among the cations is not confined, however, to the three bases, calcium, magnesium, and potassium. The relationship of sodium, particularly in sodium-accumulating plants, has already been mentioned. As far as the authors are aware, the interactions between calcium, magnesium, and potassium, and the heavy metals, manganese, copper, iron, and probably zinc, have not been recognized. Data obtained from experiments on tung show definite relationships to exist between the accumulation in the leaves of the three bases, calcium, magnesium, and potassium, and the accumulation of manganese, zinc,

copper, and iron. Growth and fruiting responses of the plants and "symptoms" also indicate that a proper balance between the concentrations of these last four elements in the leaves and between their concentrations and those of calcium, magnesium, and potassium, is of utmost importance in producing normal growth and plants free of symptoms of malnutrition.

The appearance of symptoms associated with manganese deficiency has been found to be associated with a high accumulation of any one of the three major bases and to be most severe when all three are high in proportion to manganese. Thus conditions promoting increased accumulations of calcium, magnesium, and potassium work in two ways to produce manganese "deficiency"; first, by depressing the accumulation of manganese, and second, by increasing the concentration of manganese required in the leaf to create a proper balance with the other elements.

The same situation with regard to copper and iron has also been apparent in the authors' studies. Though the zinc content of the authors' material has not yet been determined, the appearance of zinc "deficiency" symptoms and reduced rate of growth indicate a similar situation with respect to that element.

The importance of the proper balance between boron and the major bases, particularly calcium, has been pointed out by a number of workers (5, 14, and others). Chapman and Brown (4) have also observed a relationship between potassium and boron.

In the authors' work boron "deficiency" and "toxicity" have consistently been associated with an unbalanced ratio between boron and all three major bases. Low levels of the bases in proportion to boron are conducive to boron toxicity, and high levels of the bases are conducive to boron deficiency. The most pronounced relationship has been between magnesium, or more correctly, between the $\frac{Ca + K}{Mg}$ ratio and boron, a high ratio of $\frac{Ca + K}{Mg}$ consistently resulting in boron toxicity. A high $\frac{Ca + Mg}{K}$ ratio has also increased boron toxicity, but high $\frac{K + Mg}{Ca}$ ratios have had little effect on the appearance of boron toxicity.

The use of leaf content of nitrogen alone as a criterion of the nutritional status of the plant as regards that element has been suggested by Boynton and Burrell (2). In view of the evidence already presented regarding the importance of proper balance among the other elements a similar situation with respect to nitrogen is to be expected. The authors' experiments have indicated such to be the case. Not only has it been difficult materially to affect the leaf content of nitro-

gen through wide variations in continuous nitrogen supply but there has been little correlation between leaf nitrogen and growth.

The only conditions under which it has been possible materially to affect the leaf nitrogen content have been those of variable nitrogen supply during the period of growth. Reduced nitrogen content in the leaves results from an adequate supply of that element during the early part of the growing season followed by a reduced supply during the latter part of the season. Under such conditions it is probable that the reduced supply is unable to meet the nitrogen demands of the growth stimulated by the higher early nitrogen supply. Under conditions of inadequate nitrogen supply during the grand period of growth followed by an increase in the supply, excess nitrogen accumulation may result probably because of the inability of the plant to utilize the increased available nitrogen in further growth.

Such variations in nitrogen supply resulting from variable climatic and soil conditions undoubtedly are responsible for fluctuations in the nitrogen content of field grown plants that are not correlated with growth.

Interpretation of the nitrogen analysis of leaves thus presents perhaps the most difficult of all problems in foliar diagnosis. This is due to a number of factors that influence nitrogen accumulation and utilization. Perhaps the most important of these is the occurrence of nitrogen both in the substrate and within the plant in both anionic and cationic form. The form in which the nitrogen is available and absorbed influences not only the accumulation and utilization of nitrogen, but also affects the accumulation and function of all of the other elements. Thus, when nitrogen is supplied as the ammonium ion it enters into the cationic competitive series, while in the form of the nitrate ion it is in the anionic competitive series. The situation is further complicated by the fact that once within the plant, the ionic form of nitrogen greatly affects its assimilation. The generally high total nitrogen content of the leaves of plants supplied with ammonium nitrogen is undoubtedly due to its more rapid assimilation when supplied in the already reduced form. The lack of increased growth in proportion to the increased nitrogen accumulation under conditions of ammonium nutrition is probably due to the differential depressing effect of the ammonium ion on the other cations which results in an unbalanced ratio between the bases.

Interpretation of the nitrogen content of the leaves in terms of the nitrogen status of the plant is further complicated by another unique behavior of nitrogen. This is the fact that nitrogen, particularly when supplied as nitrate, accumulates in the leaves only to the extent to which its available supply will permit growth. In other words, if the intensity and balance of the other elements are favorable for a high growth potential, growth will be in proportion to the available nitrogen supply and accumulation of nitrogen above the level permitted by this intensity and balance will be prevented by its utilization in additional growth.

A specific example of the effect of an essential element, namely copper, on the accumulation and utilization of nitrogen can be cited

from the work of Gilbert *et al.* (7). They state that nitrogen applications to tung trees in early stages of copper deficiency failed to increase linear growth but greatly increased the incidence of copper deficiency. Their analyses of leaves sampled on October 23 show that the leaves from copper deficient trees which made little or no growth contained 2.33 per cent nitrogen and 6.5 ppm of copper as compared with 1.80 per cent nitrogen and 12.1 ppm of copper in the normal trees making satisfactory growth.

Further evidence that increased nitrogen content in the leaves is not necessarily accompanied by increased growth and is not by itself a reliable criterion of the nitrogen status of the plant is found in the work of Merrill and Greer (13) on the fertilization of tung seedlings. They state that, "There was no response to nitrogen unless phosphorus was applied to the soil, and considering the level of precision of the experiment, it is questionable if there was an actual response to phosphorus unless nitrogen was applied." Their growth measurements show an increase, however, of 109 per cent in total shoot growth when both nitrogen and phosphorus (P_2O_5) were each applied at the rate of 40 pounds per acre. They present only a summary of their leaf analysis data but the original data show that nitrogen application alone increased the leaf nitrogen from 2.26 per cent to 2.59 per cent but did not significantly effect the phosphorus content while the phosphorus application alone increased the leaf content of phosphorus from 0.108 per cent to 0.140 per cent and the nitrogen from 2.26 per cent to 2.48 per cent. When both nitrogen and phosphorus were applied, the leaf nitrogen increased from 2.26 per cent to 2.67 per cent and the phosphorus from 0.108 per cent to 0.117 per cent.

Much work is needed in order to determine the factors influencing nitrogen accumulation and the relationships between nitrogen nutrition and the accumulation and function of other nutrients.

Many other relationships between the available supply and the accumulation of mineral nutrients and other instances of decreased growth or other symptoms of malnutrition resulting from improper nutritional balance within the plant as indicated by leaf analyses, have been demonstrated by the authors' work on tung. A complete report on this work is in preparation.

The more important principles of the concept of nutrient-element balance and intensity have been presented here in the hope that they may stimulate further work in this field. The authors are convinced that the principles involved are generally applicable and that the acceptance of leaf analysis as the most practical means of determining fertilizer requirements depends only upon the accumulation of sufficient data on each crop plant to enable the setting up of standards upon which to base interpretation.

The concept as presented herein is admittedly incomplete and the authors fully appreciate the fact that much future work is necessary for an adequate understanding of all of the factors involved. Such work should contribute much to our fundamental knowledge of plant nutrition and also find tremendous practical application in modern agricultural practices.

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Testing the Significance of Observations Compared with a Control

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IN THE application of the analysis of variance when treatments of about equal efficacy are compared with a control, frequently no significant F-value results even though all treatments produce results superior to the control. Sometimes an investigator, feeling a statement of significance is justified, employs the ordinary t-test even after a non-significant variance ratio has been obtained. Certainly when the variance-ratio test does not demonstrate significant differentiation, much caution should be used before claiming significance for special comparisons.

Occasionally several treatments are compared with a control and the ordinary t-test is employed with no recognition of the fact that it is applicable only when one compares two treatments selected at random. In this case one is comparing selected pairs and more stringent tests of significance should be applied than when a single pair is taken at random. It is the purpose of this paper to supply a modified t-table applicable to tests of this kind.

Suppose we have n treatments which are being compared with a control giving n differences. We wish to test if the *largest* ratio, t', difference/standard error, is significant. Denote by P the probability that errors of random sampling would give a *single* difference equal to or greater than some value d, and let P_n be the probability that the largest of n differences would equal or exceed d. Then $(1-P)$ is the probability that *one* random difference should be less than d and $(1-P_n)$ is the probability that n differences would be less than d.

Since if a number of independent events have certain probabilities of occurrence, the probability of all occurring together is the product of the separate probabilities, we have

$$(1-P)^n = 1-P_n$$

from which

$$\log(1-P) = \frac{1}{n}\log(1-P_n)$$

At the 5 per cent level of significance

$P_n = 0.05$ and $\log(1-P) = \frac{1}{n}\log 0.95)$ from which $(1-P)$ may be calculated and the area, $P' = 1-\frac{1}{2}P$, under the normal curve from $-\infty$ to a value t' = (greatest difference/standard error) can be determined.

By entering Student's t-table [1] with values of the probability P', corresponding values of t' for degrees of freedom greater than 2 can be determined. The values of t' for 1 and 2 degrees of freedom may be calculated directly from the expressions

$$t' = \tan(P'-0.5)(180 \text{ degrees})$$

and

$$t' = 2\tan\sin^{-1}2(P'-0.5) \text{ respectively.}$$

The results for two to eleven samples are summarized in the following table in which the upper entry is the value of t' to be expected at

the 5 per cent level of significance and the lower that at the 1 per cent level.

TABLE I—SUMMARY OF RESULTS FOR TWO TO ELEVEN SAMPLES

$t' = \text{Largest} \frac{\text{Deviation}}{\qquad}$ (Upper values, 5 per cent level of significance; lower, 1 per cent level)

Degrees of Freedom for Error Variance	Number of Samples									
	2	3	4	5	6	7	8	9	10	11
1	12.7	25.2	37.4	49.7	62.4	74.9	87.2	99.5	111.7	124.9
	63.7	127.3	191.2	255.0	318.8	375.1	456.7	489.9	579.8	5093.5
2	4.3	6.2	7.6	8.8	9.8	10.8	11.6	12.4	13.2	14.0
	9.9	14.1	17.4	20.0	22.3	24.2	26.7	27.8	30.2	31.6
3	3.2	4.2	4.8	5.4	5.8	6.2	6.5	6.9	7.1	7.4
	5.9	7.5	8.7	9.7	10.3	11.0	11.6	12.2	12.7	13.1
4	2.8	3.5	3.9	4.3	4.6	4.8	5.0	5.2	5.4	5.6
	4.6	5.6	6.3	6.8	7.2	7.5	7.9	8.0	8.5	8.7
5	2.6	3.2	3.5	3.8	4.0	4.2	4.4	4.5	4.6	4.8
	4.0	4.8	5.3	5.7	5.9	6.2	6.2	6.6	6.8	6.9
6	2.4	3.0	3.3	3.5	3.7	3.9	4.0	4.1	4.2	4.3
	3.7	4.3	4.8	5.0	5.2	5.4	5.6	5.7	5.9	6.0
7	2.4	2.8	3.1	3.3	3.5	3.6	3.7	3.8	3.9	4.0
	3.5	4.0	4.4	4.6	4.8	5.0	5.1	5.2	5.4	5.5
8	2.3	2.7	3.0	3.2	3.3	3.5	3.6	3.7	3.7	3.8
	3.4	3.8	4.2	4.3	4.5	4.7	4.8	4.9	5.0	5.1
9	2.3	2.7	2.9	3.1	3.2	3.4	3.5	3.5	3.6	3.7
	3.3	3.7	4.0	4.2	4.3	4.4	4.5	4.6	4.7	4.8
10	2.2	2.6	2.9	3.0	3.2	3.3	3.4	3.4	3.5	3.6
	3.2	3.6	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.6
11	2.2	2.6	2.8	3.0	3.1	3.2	3.3	3.4	3.4	3.5
	3.1	3.5	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5
12	2.2	2.6	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.4
	3.1	3.4	3.7	3.8	4.0	4.0	4.1	4.2	4.3	4.3
13	2.2	2.5	2.7	2.9	3.0	3.1	3.2	3.3	3.3	3.4
	3.0	3.4	3.6	3.7	3.9	4.0	4.1	4.1	4.2	4.2
14	2.1	2.5	2.7	2.9	3.0	3.1	3.1	3.2	3.3	3.3
	3.0	3.3	3.6	3.7	3.8	3.9	4.0	4.0	4.1	4.1
15	2.1	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3
	3.0	3.3	3.5	3.6	3.8	3.8	3.9	4.0	4.1	4.1
16	2.1	2.5	2.7	2.8	2.9	3.0	3.1	3.1	3.2	3.3
	2.9	3.3	3.5	3.6	3.7	3.8	3.9	3.9	4.0	4.0
17	2.1	2.5	2.6	2.8	2.9	3.0	3.0	3.1	3.2	3.2
	2.9	3.2	3.4	3.6	3.7	3.7	3.8	3.9	4.0	4.0
18	2.1	2.4	2.6	2.8	2.9	3.0	3.0	3.1	3.1	3.2
	2.9	3.2	3.4	3.5	3.6	3.7	3.8	3.9	3.9	3.9
19	2.1	2.4	2.6	2.8	2.9	2.9	3.0	3.1	3.1	3.2
	2.9	3.2	3.4	3.5	3.6	3.7	3.8	3.8	3.8	3.8
20	2.1	2.4	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.1
	2.8	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.8	3.8
∞	2.0	2.2	2.4	2.5	2.6	2.6	2.7	2.7	2.8	2.8
	2.6	2.8	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.3

The use of the table will be indicated in the analysis of yields of a certain field crop subjected to three treatments planted in a randomized block design with a control. The yields in pounds are as shown in Table II.

TABLE II—ANALYSIS OF YIELDS BY USE OF TABLES

Blocks	Treatments			
	A	B	C (Control)	D
1	13.6	10.5	9.5	10.2
2	8.8	11.2	7.0	11.8
3	9.0	11.7	7.5	10.1
4	10.1	8.3	7.8	7.9
5	7.8	8.7	6.8	8.7
Mean yield	9.9	10.1	7.7	9.7

Variance analysis leads to an error variance of 1.83 with 12 degrees of freedom and an F-value of 3.3 with 3 and 12 degrees of freedom. At the 5 per cent-level the value required for significance is 3.49. Although no significance is indicated, in every block the yield of any plot subjected to a treatment is greater than the yield of the control plot, and the mean yield of all plots subjected to any treatment is at least 25 per cent greater than the mean yield of all control plots. Certainly the treatments appear to have had some effectiveness in increasing yield. If one proceeds to calculate the difference between the mean yield of treatments required for significance using the ordinary t-value (2.18), $d = 2.18\sqrt{\frac{2(1.83)}{5}} = 1.9$ lbs., and one finds that all treatments are significantly better than the control at the 5 per cent level. Using the value of t' (2.8) for four samples and 12 degrees of freedom instead of t in the above formula, the difference between means required for significance is 2.5 pounds which indicates that the greatest difference is not significant, a result consistent with the non-significant F-value.

If a randomized plot pattern had been employed instead of a randomized block design, the error variance would have been increased to 2.68 with 16 degrees of freedom and the difference between means required for significance using an ordinary table of t-values would be 2.2 pounds indicating a significant difference between treatment A and the control. Using the value of t' for 4 samples and 16 degrees of freedom the difference required for significance between the control and the greatest mean yield, treatment A, must be 2.8 pounds which indicates no significant difference in yield.

In problems comparing with a control the greatest mean deviations therefrom values of t' should be used instead of the ordinary values of t.

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The Decomposition of Certain Plant Tissues with and without Added Lignin[1]

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THE rate of decomposition of plant material, other factors being equal, is believed to be dependent upon the relative amounts of lignin, cellulose and hemicellulose (4, 7). Although under certain conditions the rate of decomposition of lignin may be as great as that of cellulose and pentosans (6), in normal combination in the plant the decomposition of cellulose is retarded considerably (5, 9). When isolated lignin is mixed with cellulose no such effect is noted (9). However, under anaerobic conditions the addition of isolated lignin has been shown to exert a very definite retarding effect upon the decomposition of actively digesting sludges (1, 3). The reasons for this behavior are not definitely known, although there are several possible explanations (1, 3, 8). Instances have also been reported in which the plant residues apparently have affected the growth of the subsequent crops (2).

The investigation here reported deals with the rate of decomposition of four different plant materials with and without the addition of large amounts of isolated lignin.

Corn silage which had been preserved for about 3 months, timothy hay, mature corn stalks, and oat hay were used in this investigation. All materials were ground to pass a 1-mm sieve. A partial chemical analysis is shown in Table I.

TABLE I—THE PERCENTAGE CONTENT OF TOTAL NITROGEN, TOTAL ASH, CRUDE LIGNIN, AND PENTOSANS ON A DRY MATTER BASIS IN THE PLANT TISSUES USED

Item	Total Ash	Total Nitrogen	Crude Lignin	Pentosans
Oak straw	10.02	1.38	13.77	18.32
Timothy hay	5.36	1.41	10.37	18.06
Corn silage	5.57	1.27	6.13	15.63
Corn stalks	8.07	1.19	11.02	18.32

Four equal amounts of each plant tissue were weighed out, to two of which isolated lignin was added in amounts equivalent to about 13 per cent of the weight of the plant tissues used, while the other two served as controls. One gram of nitrogen in the form of ammonium carbonate was added to all, for every 100 grams of original material. The lignin used was a commercial product known as Meadol, prepared and supplied by the Mead Corporation, Chilicothe, Ohio. This sample had a carbon and hydrogen content of 64.2 and 5.6 per cent respectively. The lignin was thoroughly mixed with each substance. The ammonium carbonate was added from a burette. The entire sample was then treated with a soil inoculum, then thoroughly wetted, mixed, and transferred to large wide-mouth glass jars. The lids were attached loosely and the jars placed in an oven operating at about 30 degrees C

[1]Contribution No. 593 of the Massachusetts Agricultural Experiment Station.

for 2 days, in order to allow an equilibrium to become established. At this time and at subsequent intervals of several days, approximately 60 grams of representative material were removed from each of the parallels and quickly weighed. In this way chemical changes within the mass could be determined over the period of incubation. Analyses were made in duplicate. The moisture content during incubation averaged about 70 per cent. The samples were kept moist by adding water with a sprayer, then mixing the material by rotating the jars. Rotations were made frequently to insure more uniform microbial activity. Table II contains data which indicate some of the changes which occurred during the period of decomposition.

TABLE II—THE AMOUNT OF DRY MATTER, TOTAL AND AMMONIACAL NITROGEN AND pH OF DECOMPOSING PLANT TISSUE WITH AND WITHOUT LIGNIN PER 100 GRAM OF ORIGINAL DRY MATTER

Number of Days	With Lignin				Without Lignin			
	Dry Matter (Gms)	Total Nitrogen (Gms)	Ammoniacal Nitrogen (Gms)	pH	Dry Matter (Gms)	Total Nitrogen Gms)	Ammoniacal Nitrogen (Gms)	pH
				Silage				
0	100	2.41	1.18	6.2		2.41	1.18	5.8
13	84.9 ±4.5	2.39	0.83	8.1	86.3 ±1.6	2.35	0.95	8.0
28	77.3 ±4.9	2.36	0.89	6.7	76.4 ±1.0	2.40	0.96	5.6
50	65.2 ±2.9	2.36	0.87	9.0	59.6 ±0.4	2.25	1.01	8.9
63	60.5 ±1.9	2.22	0.85	8.6	55.7 ±0.8	2.15	0.96	9.0
				Timothy				
0	100	2.58	0.96	8.3		2.58	0.96	8.1
13	87.2 ±1.4	2.33	0.90	8.4	84.0 ±0.1	2.41	0.92	8.6
28	77.4 ±1.3	2.43	0.93	8.3	75.7 ±1.1	2.35	0.95	8.4
50	70.0 ±0.4	2.41	0.79	9.2	69.2 ±1.1	2.21	0.93	9.1
63	66.1 ±0.4	2.36	0.73	8.7	59.8	2.12	0.88	8.7
				Corn Stalks				
0	100	2.68	1.52	8.4		2.68	1.52	8.3
13	87.5 ±0.3	2.64	1.33	8.7	87.4 ±0.2	2.32	1.40	8.9
28	80.0 ±0.9	2.58	1.16	8.6	81.1 ±1.0	2.30	1.30	8.6
50	71.5 ±3.5	2.51	0.80	8.9	73.0 ±0.9	2.16	0.99	8.9
63	62.3 ±4.5	2.30	0.65	8.7	68.9 ±1.4	2.11	0.93	8.6
				Oat Hay				
0	100	2.39	0.93	8.4		2.39	0.93	8.6
13	68.3 ±0.6	1.82	0.83	8.6	92.4 ±0.5	2.17	1.11	8.8
28	60.6 ±0.4	1.80	0.66	8.6	87.5 ±1.5	2.14	1.05	8.9
50	54.9 ±0.1	1.69	0.58	9.2	74.3 ±2.3	2.11	0.74	9.1
63	48.2 ±2.5	1.65	0.35	8.6	69.1 ±2.6	2.04	0.73	8.9

The percentage content of lignin in oat straw, corn stalks and timothy hay is quite similar. On this basis alone one would suspect that the materials would decompose in the following order: oat hay < corn stalks < timothy hay < silage. In the control samples this is the order that was followed; in the presence of added lignin, however, this order was not followed. The data indicated that the presence of added lignin did not retard significantly the decomposition of silage and timothy hay and actually accelerated that of corn stalks and oat hay, especially the latter. This does not imply that lignin is an accelerator for the decomposition of plant tissue, but rather that its presence under certain conditions is not inhibitory.

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Ascorbic Acid in Fruits of Tomato Varieties and F_1 Hybrids Forced in the Greenhouse

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Introduction

The objective of the experiments reported here was to determine the relative ascorbic acid content in fruits of tomato varieties and lines in use and considered for use as parents in developing a type adapted to forcing culture in the Central Great Plains and Rocky Mountain region. During recent years several investigators (2, 7, 9, 14, 19, 20, 23) have reported varietal differences in ascorbic acid content of tomatoes. These and other investigators (5, 6, 11, 12, 13, 16) noted the effects of various environmental factors on the ascorbic acid concentration of tomatoes.

Materials and Methods

Experimental Design:—Eighteen tomato varieties, selected from preliminary yield tests in 1942 and 1943, were seeded in pots in the greenhouse April 24, 1944 and transplanted to a greenhouse bed June 8, with a spacing of 18 by 27 inches. Day temperatures ranged between 70 and 95 degrees F, and night temperatures between 50 and 65 degrees F. The plants were pruned to one stem, tied to supports and topped at 6 feet. Water was applied by furrows to maintain good growing conditions, and the attempt was made to irrigate all plants equally. The plants were arranged in three blocks randomized by Tippet's (22) tables, with a three-plant row of each variety in each block. The pots were randomized at seeding and this arrangement was maintained throughout the growing period. Single buffer rows were placed on the west, south, and east sides of the plot. Space prevented the use of a buffer row adjacent to the walk on the north side, which was the more shaded side of the planting. However, there was no significant difference in growth or yield of plants in this outside row and those in the other rows.

Sixteen F_1 variety hybrids and two of the varieties used in the variety test just described were included in a second planting in an adjacent greenhouse. The arrangement was the same as in the variety test. The F_1 hybrids included in the yield test were obtained from crosses between selected lines and various commercial varieties. Because the primary objective was to determine which of several types of crosses would be of most value in obtaining high yields, it was necessary to include several F_1 hybrids in this preliminary yield test, and space limitations prevented the inclusion of all parents of these hybrids. A high yielding variety (Lloyd Forcing) and a high quality variety (Uniform Globe) were included in the hybrid test to serve as standards for comparison.

Sampling Methods:—Fruits were harvested in the morning, yields recorded, and the samples taken to the laboratory for immediate analysis. Analyses were made on samples obtained from the three blocks in

three harvests at weekly intervals during the peak harvest period in September. Thus, determinations were made on nine samples from each variety or F_1 hybrid. Three uniformly ripe fruits from each row were used at each harvest date in the experiments reported here. Each ascorbic acid determination was made on a composite sample of equivalent equatorial slices from three fruits from a plot.

Chemical Analysis:—For the analyses, a modification of the Heinze-Kanapaux (8), and Loeffler and Ponting (10) methods was used. The composite sample from three fruits (20 to 50 grams) was weighed to the closest 0.1 gram. About 125 ml of 2 per cent meta-phosphoric acid was added, this mixture was blended in a Waring Blendor for 2 minutes, transferred quantitatively to a 200 ml volumetric flask, made to volume with 2 per cent meta-phosphoric acid, shaken and filtered. After discarding the first 20 to 30 ml of filtrate, a 1 ml aliquot was transferred to a colorimeter tube. Nine ml of standardized[1] sodium 2,6-dichlorobenzenoneindophenol dye solution, containing 20 mg of dye in a liter of water was added, the tube shaken and read immediately in the Klett-Summerson colorimeter. A few crystals of ascorbic acid were then added to decolorize the remaining dye, the tube shaken and read again to obtain a figure compensating for turbidity and color in the sample. The concentration of ascorbic acid in the sample was calculated from the equation

$$\frac{C-(A-B) \times D \times 100}{\text{Weight of tomato in aliquot}} = \text{Mg. of ascorbic acid in 100 grams fresh fruit, where}$$

C = Reading of 9 ml. dye plus 1 ml. meta-phosphoric acid (dye blank)
A = Reading of 9 ml. dye plus 1 ml. tomato extract (sample)
B = Reading of sample plus ascorbic acid crystals (sample blank)
D = Ascorbic acid factor of dye solution.

The use of the *sample blank* compensated for turbidity and color in the sample and obviated refiltering to obtain a clear filtrate. The final figure depended on a difference in the concentration of the dye caused by the reducing action of ascorbic acid in the sample. Bessey (1) applied this method, but used a separate aliquot of the extract to obtain the *sample blank*. Use of the same aliquot saved considerable time and was equally accurate. By using this method, a crew of three made an average of 30 determinations an hour. It is believed that greater accuracy was obtained by compensating for color and turbidity on each separate sample than by setting the colorimeter at zero with one sample (18) which had been decolorized with ascorbic acid and using this

[1]A solution containing about 20 mg of this dye in a liter of water was standardized with a series of standard solutions of pure ascorbic acid in 2 per cent meta-phosphoric acid, which in turn had been standardized against standard iodine solution. A Klett-Summerson colorimeter with No. 54 filter was set at zero with distilled water. Nine ml of the dye solution and 1 ml of 2 per cent meta-phosphoric acid were mixed in a colorimeter tube and read immediately. This dye blank reading was checked daily because the dye fades slowly in light. Nine ml of the dye solution and 1 ml of standard ascorbic acid solution were mixed and read immediately. The ascorbic acid factor for the dye solution was obtained by dividing the weight of ascorbic acid in the standard by the difference between the dye blank reading and the standard solution reading. Readings on standards containing different known concentrations of ascorbic acid demonstrated that Beer's Law holds for the methods and materials used.

setting on all samples. The tomato extracts varied in color, and the use of one blank for all samples would have introduced an avoidable error.

Ascorbic Acid Concentration in Fruits of Tomato Varieties

An analysis of variance by the methods described by Snedecor (21) of the data on ascorbic acid concentration in fruits of the tomato varieties showed statistically significant differences[2] in ascorbic acid content of fruits of different varieties, of fruits collected from different blocks, and of fruits collected at different dates. The variation resulting from the interaction between varieties and blocks was also statistically significant. Other interactions did not cause significant variation. Before considering varietal differences, it is necessary to consider the other causes of variation.

The significant differences in ascorbic acid content of fruits collected from different blocks (means equal 29.86, 34.11, and 34.62 mg in 100 grams of fresh fruit) and on different dates (means equal 31.41, 33.73, and 33.45) indicate that unknown factors in the environment affected the ascorbic acid concentrations in these tomatoes. It is possible that light was an important factor in causing these variations as ascorbic acid concentrations were highest in fruits collected from block 3 on the side of the planting facing the sun, and in fruits collected at higher levels on the plants at the later dates.

The statistically significant F value for the interaction between varieties and blocks indicated that the relationship among varieties varied with location within blocks. It was noticed that plants at one end of blocks two and three grew less vigorously and set fewer fruits than the same varieties in other locations. It is possible that the significant interaction resulted from the various positions of plants within blocks in these two general areas. After planting, the soil in the area where plants grew less luxuriantly settled more than did the soil in the other areas. This resulted in a tendency for water to accumulate in this area during irrigations. It is possible that differences between plants in the two areas resulted from differences in soil moisture or related factors.

The ranges and means of ascorbic acid content in fruits of the varieties are presented in Table I. The first eight varieties listed in Table I had significantly greater concentrations of ascorbic acid in their fruits than did Uniform Globe, the variety arbitrarily selected as a standard in the forcing variety tests because of its high quality and other desirable economic characters (3).

Ascorbic Acid Concentration in Fruits of F_1 Hybrids

An analysis of variance of the data on ascorbic acid content of fruits of the F_1 variety hybrids indicated that statistically significant differences in ascorbic acid content of fruits resulted from differences among hybrids, among blocks, among dates of harvest, and from the interaction between hybrids and blocks. The other interactions were not significant. The mean ascorbic acid concentrations (mg in 100 grams

[2]Values approaching or exceeding the 1 per cent level are interpreted as having significance. Values near the 5 per cent level are considered to have doubtful significance; values below the 5 per cent level are considered non-significant.

TABLE I—RANGES AND MEANS OF ASCORBIC ACID CONTENT (NINE SAMPLINGS) AND THE AVERAGE FRUIT WEIGHTS OF, (A) TOMATO VARIETIES, AND (B) F_1 VARIETY HYBRIDS FORCED DURING THE SUMMER OF 1944 AT CHEYENNE, WYOMING

	Ascorbic Acid Mg in 100 Grams			Average Fruit Size Grams Per Fruit
	Maximum	Minimum	Means	
(A) Varieties				
Crackerjack Forcing	48.65	32.66	40.20	78
Comet Forcing	43.14	32.98	37.12	94
Long Calyx Forcing	44.29	30.80	36.77	116
Imp. Crackerjack Forcing	44.71	27.91	35.47	101
Hundredfold Forcing	43.02	26.43	34.39	76
Bay State Forcing	40.09	31.03	34.21	85
Waltham Forcing	38.47	27.13	34.13	94
Listers Protection Forcing	45.01	28.26	33.79	65
Blair Forcing	42.29	27.05	33.45	86
Sureset Forcing	39.40	26.30	32.66	117
Urbana Forcing	39.74	26.48	31.40	136
Marhio	36.84	20.37	30.81	165
Glovel	36.64	23.38	30.55	171
Gulf State Forcing	37.21	20.79	29.80	151
Uniform Globe	34.27	23.75	29.71	126
Michigan State Forcing	35.68	21.30	29.34	147
Lloyd Forcing	33.77	21.92	28.98	135
Grand Rapids Forcing	37.63	23.40	28.71	95
Significant difference 5%			2.87	20
Significant difference 1%			3.82	26
(B) Variety Hybrids				
Early Line 65–5 ×Early Jumbo	40.37	27.60	34.08	80
Early Line 164–11 ×Ponderosa	36.98	29.09	32.61	91
Early Line 164–11 ×Uniform Globe	39.55	23.48	31.73	103
Uniform Globe Line 10 ×Bay State	31.45	22.10	26.92	88
Early Line 462–3 ×Uniform Globe	31.54	20.42	26.65	103
Lloyd Forcing	29.84	18.70	25.86	124
Uniform Globe	31.06	22.00	25.77	141
Early Line 164–11 ×Oxheart Line 5	30.58	20.25	25.66	90
Uniform Globe ×Determinate Pink	30.76	18.90	25.51	86
Danmark Line 7 ×Uniform Globe	31.61	19.80	25.16	81
Early Line 26–7 ×Early Jumbo	30.04	19.22	25.07	86
Early Line 164–11 ×Oxheart Line 1	33.68	20.62	25.02	82
Uniform Globe ×Glovel	36.93	17.06	24.78	148
Uniform Globe ×Bounty	32.18	18.59	23.53	140
Early Line 462–3 ×Oxheart Line 1	37.51	18.51	22.55	121
Early Line 462–3 ×Oxheart Line 5	32.53	15.99	21.33	116
Bounty ×Oxheart Line 1	24.95	17.82	20.53	176
Bounty ×Oxheart Line 5	21.76	14.78	18.67	142
Significant difference 5%			2.72	20
Significant difference 1%			3.62	26

of fresh fruit) in fruits of all hybrids collected at the three dates of harvest were 23.79, 25.93, and 27.19, respectively. The means for fruits collected from blocks 1, 2, and 3 were 23.38, 27.54, and 25.98 respectively. These data are similar to those obtained from the variety test, but no marked difference in plant growth was noticed in different areas of the test plot.

The mean ascorbic acid content of fruits of different hybrids are presented in Table I. Three of the F_1 variety hybrids contained significantly greater concentrations of ascorbic acid than did Uniform Globe, used as a standard, and three had significantly lower concentrations. None of the hybrids had particularly high concentrations of ascorbic acid; there was little indication that heterosis had a favorable effect on ascorbic acid content of these tomatoes. Biryukov (2) and Reynard and Kanapaux (19) found tomato hybrids from crosses between par-

ents of high and low ascorbic acid content to have concentrations intermediate between those of the parents.

Ascorbic Acid Concentration and Fruit Size

McHenry and Graham (17) and Reynard and Kanapaux (19) found ascorbic acid to be negatively correlated with fruit size in tomato varieties varying greatly in size. Other workers (14, 15, 23, 24) found no correlation between ascorbic acid and fruit size within varieties or strains of tomatoes. Such correlations as have been found might be due to environmental factors affecting fruit size and ascorbic acid content or to genetic linkages or to heritable physiological association.

Before considering the correlations of fruit size and ascorbic acid concentrations in the experiments reported here, analyses of variance of fruit weights were made to determine whether there were statistically significant variations in fruit weights among the varieties and among the variety hybrids. In the variety test, differences among varieties and differences among harvest dates were the only causes of significant variation in fruit weight; in the F_1 hybrid test, only differences among hybrids caused significant variation. The decline in average fruit weight of the varieties with time was associated with a decline in vegetative vigor as the season progressed. The plants in the hybrid experiment continued to grow vigorously until they were discarded in October. Apparently, certain factors causing variation in ascorbic acid concentration were less effective in causing variation in weight of fruits. The mean fruit weights for the varieties and for the F_1 hybrids are included in Table I.

The data presented in Table I suggest that mean fruit weights for varieties and mean ascorbic acid content of fruits of varieties were negatively correlated. However, the correlation coefficient for these characters among varieties was below the five per cent point and indicated that this apparent difference between varieties was not significant. There was a significant negative total correlation that could not be attributed to differences among varieties or to differences caused by positions of plants in the greenhouse or to dates of harvest. These data suggest that undetermined environmental factors were more important as causes of correlation between ascorbic acid content and fruit weight than were hereditary factors.

As with the data on varieties, the means for ascorbic acid concentration and fruit weights in F_1 hybrids (Table I) suggested a negative correlation between ascorbic acid content and fruit size. Here, a significant negative correlation between fruit weight and ascorbic acid concentration could be attributed to differences among F_1 hybrids.

Discussion and Summary

Statistically significant differences in ascorbic acid concentration were found to occur among different varieties and among different F_1 variety hybrids. These data indicate that ascorbic acid concentration in tomato fruits is controlled partly by heritable genetic factors and can be manipulated by genetic methods. The data suggest that F_1 hybrids may have little or no advantage over varieties in so far as ascorbic acid concentration in fruits is concerned.

Negative correlation between large fruit size and high ascorbic acid concentration in the variety test could not be attributed to varieties, blocks, or dates of harvest. In the F_1 hybrid test significant negative correlation between these characters was caused principally by differences among hybrids. This difference between the results of the two experiments may have been caused by differences in plant vigor. While ascorbic acid concentration increased with time in both experiments, fruit size and apparent plant vigor decreased in the variety test but remained relatively constant in the hybrid test.

Relatively large variations caused by undetermined environmental factors suggest that greater accuracy is desirable for comparisons of ascorbic acid concentrations in tomato varieties. This substantiates the findings of other workers. It seems desirable that critical studies be made of environmental factors affecting ascorbic acid concentrations in tomato fruits to facilitate production of tomatoes with high ascorbic acid concentrations and to facilitate genetic and breeding studies. Factors deserving particular attention might include soil moisture, soil aeration, soil and air temperatures, and light.

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Breeding Tomatoes for Nematode Resistance and for High Vitamin C Content in Hawaii[1]

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The root knot nematode, *Heterodera marioni* (Cornu) Goodey, causes serious economic losses throughout the tropics and in the warmer parts of the temperate zone. In Hawaii yields of tomatoes may be reduced an estimated 50 to 75 per cent in severely infested fields. Chemical fumigation of the soil is expensive and provides only temporary control. A more permanent solution would be offered through the development of resistant varieties.

The tomato, the most important and universal vegetable source of vitamin C, shows a wide varietal and species variation in this important vitamin. The wild species, *Lycopersicon peruvianum* (L.) Mill., has been shown by Reynard and Kanapaux (7) to possess a high vitamin C content as compared to *L. esculentum* Mill. This wild species is also highly resistant to the root knot nematode.

The occurrence of these two desirable characters in one species has made it advantageous to conduct the initial hybridization and testing work simultaneously. The results of this preliminary work are presented in this report.

Breeding for Nematode Resistance

The development of a tomato variety resistant to the root knot nematode was started at the Hawaii Agricultural Experiment Station in 1944. A replicated field test of 30 commercial varieties in addition to the wild species *L. peruvianum* (L.) Mill. and *L. pimpinellifolium* (Jusl.) Mill. showed that *L. peruvianum* was outstanding for resistance. This agreed with the results of Bailey (1), Ellis (4), and Romshe (8). None of the commercial varieties or the species *L. pimpinellifolium*, possessed any appreciable resistance. These results made it apparent that an interspecific cross was necessary. In addition, the necessity of developing an accurate method of testing segregating populations was emphasized by variations in nematode infestation observed in this test.

Method of Testing for Nematode Resistance:—Field tests for nematode resistance under conditions of natural infection have shown that such tests are unreliable because the distribution of nematodes is not uniform in the field. Uniform seedling tests have been obtained in the greenhouse with beans and cowpeas by Barrons (2) and with tomatoes by Bailey (1). The seedling test method has been used with success also in Hawaii. Rather than testing in the greenhouse it has been possible to do the testing in artificially inoculated test beds constructed out of doors. The beds are 10 feet long, 4 feet wide, and 15 to 18 inches deep. The sides and ends are constructed of concrete tile. A concrete

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bottom, while not essential, aids in preventing contamination from the subsoil and in the thorough sterilization of the enclosed soil when necessary. The beds are filled with a mixture of two and one-half parts of pasture soil to one part of either coral sand or black volcanic sand.

The beds are inoculated with thoroughly chopped roots from severely galled tomato plants which are nearing maturity. The inoculum is either mixed uniformly with the soil or placed in the row directly beneath the seed to be tested. Satisfactory results are obtained with both methods, but are more uniform when the inoculum is placed directly beneath the seed. Less inoculum is required with the row placement method, but the inoculum is more laborious to apply. Eight pounds per bed are used when the inoculum is mixed with the soil and 50 grams per row (2½ pounds per bed) has been found sufficient when placed in the row.

The tomatoes to be tested are seeded directly in the beds in rows 4 inches apart. Every third row is planted to a susceptible variety such as Pearl Harbor. The plants are thinned to 1 inch between plants following emergence. In 4 to 5 weeks the plants are removed with roots intact and classified for nematode resistance. The plants are grouped into four classes in relation to nematode galling. Plants showing no galling are placed in Class 0, those showing slight galling in Class 1, those showing moderate galling in Class 2, and those showing severe galling in Class 3. Roots from plants representing these classes have been preserved in an alcohol formalin solution for use as standards.

Hybridization and Selection for Resistance:—Rapid progress in the development of a nematode resistant tomato variety has been impossible because cross sterility has prevented the normal crossing of *L. esculentum* and *L. peruvianum*. Through the use of an embryo culture technique five interspecific hybrids have been grown to maturity. The technique used was similar to that described by Smith (9). Immature fruits between 30 and 40 days from pollination were harvested and the incompletely developed seeds removed aseptically. After the pulp was removed from the seed coat with a sterile scalpel and tweezers the ovule with seed coat intact was placed on nutrient medium. Growth and development of the transplanted embryoes were variable. One transplant developed a primary root system and first epicotyledonary leaves in 2 weeks. Other transplants remained in the nutrient medium for 5 to 6 weeks before they were ready for removal. The young seedlings were transplanted from the nutrient medium to volcanic sand and supplied with nutrient solution until the plants were 2 to 3 inches high. They were then transplanted to soil. After the plants became well established, stem cuttings were made for transplanting to the field. These cuttings were treated with a 1 : 100,000 solution of indole butyric acid for 24 hours and then allowed to root in aerated water before transplanting.

The parentage of the interspecific hybrids grown with the aid of the embryo culture technique follow:

1. T1427—[(*L. hirsutum* x Bonny Best) x (Bounty x BC–10)] x *L. peruvianum* (P.I. No. 128645).
2. T1428—Same as T1427.

3. T1429—Pearl Harbor x *L. peruvianum* (P.I. No. 127829).
4. T2425—[Pearl Harbor x (*L. esculentum* x *L. pimpinellifolium*) x *L. chilense*] x *L. peruvianum*.
5. T2426—Same as T2425.

All five of these hybrids produced vigorous F_1 plants. T1427, T1428, and T1429 were highly resistant to the root knot nematode whereas T2425 and T2426 were only moderately resistant. The resistance of T1427 as compared to its female parent is illustrated in Fig. 1. Although all five hybrids flowered abundantly, only T1427 set fruit. In addition, this hybrid possessed several other characters of value from a plant improvement standpoint. Its extreme vigor and disease resistance were demonstrated by several plants grown from stem cuttings in a heavily nematode infested area at the Poamoho Experimental Farm, Poamoho, Oahu. These plants continued to grow for more than a year, and at its peak of growth each plant measured 20 feet across. The hybrid possessed field resistance to spotted wilt, gray leaf spot, the green potato aphid (*Macrosiphum solanifolii* Ashm.), and tolerance to mosaic (strains unknown). It was susceptible to early blight and bacterial wilt.

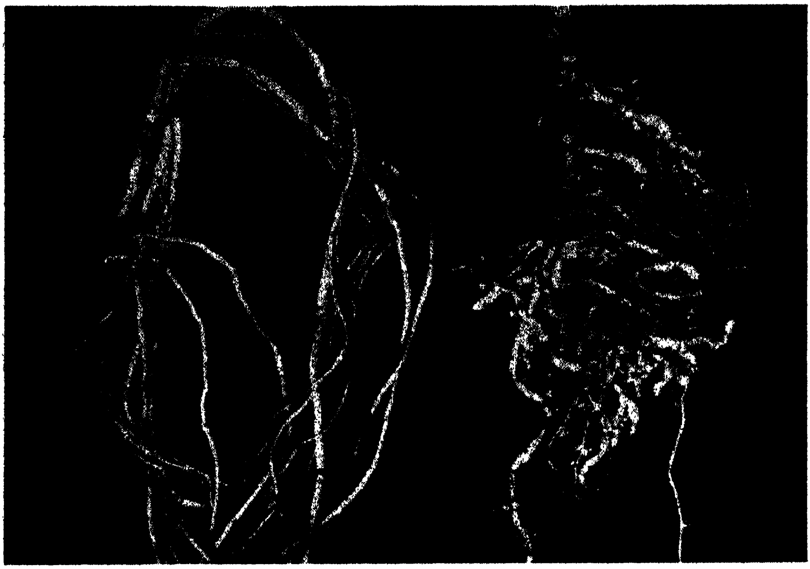

FIG. 1. A comparison of the nematode resistance of the F_1 hybrid between (*L. hirsutum* x Bonny Best) x (Bounty x BC-10) and *L. peruvianum* and the female parent of this hybrid. Resistance in this hybrid was completely dominant.

Although the hybrid flowered abundantly, the fruit set was light and sporadic. The heaviest set occurred during the late fall months. The fruits were ½ to 1 inch in diameter and were a light yellow color when mature. The growth and fruiting habits of the hybrid are shown in Fig. 2. An average of two or three viable F_2 seeds which germinated

FIG. 2. The growth and fruiting habits of the F_1 hybrid between *L. hirsutum* x Bonny Best x (Bounty x BC-10) and *L. peruvianum*. This particular plant was grown from a stem cutting from the original cross and reached a diameter of 20 feet.

without resort to embryo culture were produced per fruit. Segregation within the F_2 population was observed for vigor, plant and fruit characters, nematode resistance, gray leaf spot resistance, and fruit setting ability. The segregation for nematode resistance in the seedling stage as compared to Pearl Harbor is shown in Table I.

TABLE I—SEGREGATION FOR NEMATODE RESISTANCE IN AN F_2 POPULATION OF A CROSS BETWEEN *L. hirsutum* x BONNY BEST x (BOUNTY x BC-10) AND *L. peruvianum* AS COMPARED TO PEARL HARBOR IN AN ARTIFICIALLY INOCULATED TEST BED AT HONOLULU, HAWAII IN 1946

Variety or Cross	Number of Plants	Per Cent of Plants in Each Class*				Mean Class Value
		0	1	2	3	
T1427 F_2..........	367	22.6	67.3	10.1	—	1.10
Pearl Harbor.......	245	—	0.4	20.4	79.2	2.79

*Class 0—No injury; Class 1—slight injury; Class 2— moderate injury; Class 3—severe injury.

The F_1 was cross sterile with *L. esculentum* and has not as yet responded to embryo culture. Fruits are set following pollination but the embryoes abort early. A successful cross between *L. esculentum* and an F_2 segregate has resulted in a nematode susceptible plant.

In addition to hybridization, work has been done in testing promising nematode resistant material from other experiment stations. Eight F_3 progenies of a cross between the Michigan State Forcing variety and *L. peruvianum*, seed of which was obtained from the New Hampshire

Experiment Station, were tested in the seedling stage and promising selections then transplanted to the field. Although plants were galled in the test bed, they developed into vigorous fruitful plants in the field. Bounty plants which had been treated in a similar manner were stunted and produced only a few undersized fruits. Upon examination of the root systems it was found that the primary roots of the F_3 plants were severely galled but had succeeded in producing a heavy secondary root system which was reasonably free of galling.

Seed was saved from the most resistant F_3 plants and tests made for two more generations. Selected F_5 progenies were more resistant in the seedling stage than the susceptible Bounty variety as is shown in Table II. All of the F_5 segregates were injured by nematodes in the field; however, the galling was not as severe as on Bounty. The fruit quality of these segregates was poor and the fruit size ranged from a diameter of ¾ to 1 inch. The root systems of several of these segregates resembled *L. peruvianum*.

TABLE II—Nematode Resistance Data for Ten F_5 Populations of Michigan State Forcing x *L. peruvianum* As Compared to Bounty and *L. peruvianum* in An Artificially Inoculated Test Bed at Honolulu, Hawaii in 1945

Variety or Selection	Row Number	Number of Plants Examined	Per Cent of Plants in Each Class*				Mean Class Value
			0	1	2	3	
Bounty	1	36	—	—	67	33	2.33
HES 1697	2	30	—	10	77	13	2.03
HES 1698	3	42	—	12	71	17	2.05
Bounty	4	31	—	—	55	45	2.45
HES 1699	5	34	—	29	53	18	1.88
HES 1700	6	38	—	16	82	2	1.87
Bounty	7	38	—	2	84	14	2.11
HES 1702	8	39	—	21	71	8	1.87
HES 1703	9	38	—	32	63	5	1.74
Bounty	10	42	—	12	81	7	1.95
HES 1704	11	44	—	41	59	—	1.59
HES 1705	12	45	—	36	64	—	1.64
Bounty	13	43	—	16	79	5	1.88
HES 1706	14	28	—	21	79	—	1.79
HES 1707	15	30	—	42	58	—	1.58
Bounty	16	45	—	9	82	9	2.00
L. peruvianum	17	32	13	87	—	—	0.88

*Class 0—no injury; Class 1—slight injury; Class 2—moderate injury; Class 3—severe injury.

Considerable variation for resistance has been observed within the *L. peruvianum* species. Selections have been made which show no galling either in a heavily inoculated test bed or in the field.

Breeding for High Vitamin C Content

As has already been pointed out the occurrence of nematode resistance and high vitamin C content in the wild species *L. peruvianum* has made it advantageous to conduct the initial hybridization and selection work simultaneously. The sources of parental material, the sterility problems involved in crossing, and the progress made in interspecific hybridization have been discussed in the previous section. This section will be limited to results obtained in testing the tomato hybrids and selections already described for vitamin C content.

Method of Testing for Vitamin C:—Ascorbic acid (vitamin C) de-

terminations were made on mature fruits from plants which had been tested for nematode resistance. Many of the plants were subnormal in vigor as a result of the nematode test and were attacked by mosaic before maturity. The size of the sample used for ascorbic acid analysis was determined by the fruiting habit of the hybrid or selection from which it was collected. Normally six fruits were collected from the larger fruited selections. These fruits were divided into two groups of approximately equal weight and the samples analyzed separately. The determinations from the two groups were then averaged. Ten mature fruits were collected at random from each plant of the small fruited *L. peruvianum* species and analyzed as one sample. The tomatoes were not peeled and the entire fruit was used for analysis with the exception of samples from Bounty and Pearl Harbor. A center slice was removed from each fruit of these two varieties and these slices used as a sample for analysis. The analyses were made within 48 hours by a method developed by Morrell (5).

Vitamin C Content of Hybrids and Selections:—Selections were made at maturity from 11 F_5 populations of Michigan State Forcing x *L. peruvianum* on the basis of nematode resistance, plant vigor, and fruit characteristics. Representative fruit samples from each selection were analyzed for ascorbic acid content. Pearl Harbor, Bounty, *L. peruvianum*, and the interspecific hybrid T1427 were grown in the same location and fruit analyses made for ascorbic acid content. The results of a representative group of these analyses are shown in Table III.

TABLE III—ASCORBIC ACID CONTENT OF TOMATOES GROWN AT POAMOHO, OAHU IN 1945

Variety or Selection	Date of Analysis	No. of Fruits Analyzed	Mg of Ascorbic Acid**
HES 1966*	4-18-45	6	29.7
HES 1967	4-18-45	6	32.2
HES 1996	4-26-45	4	48.8
HES 2042	4-26-45	6	38.3
HES 2045	4-26-45	6	33.6
HES 2049	5-2-45	6	23.7
HES 2051	5-2-45	6	32.3
Pearl Harbor	4-18-45	6	13.3
Pearl Harbor	4-26-45	3	16.8
Bounty	5-2-45	7	12.0
L. peruvianum	4-18-45	16	79.2
T1427	5-2-45	6	39.7

*All HES numbers refer to F_5 selections of Michigan State Forcing × *L. peruvianum*.
**Mg. of ascorbic acid per 100 grams of fresh tomato tissue.

The ascorbic acid content of all F_5 selections from the cross Michigan State Forcing x *L. peruvianum* was higher than for the standard varieties Bounty and Pearl Harbor, but much lower than for *L. peruvianum*. The values for the selections ranged from 23.7 to 48.8 mg per 100 grams of fresh tissue. The fruit size of these selections ranged from a diameter of ½ inch to that of 1½ inches. The interspecific hybrid, [(*L. hirsutum* x Bonny Best) x (Bounty x BC-10)] x *L. peruvianum*, gave an ascorbic acid value of 39.7 mg as compared to 12.0 mg for Bounty analyzed on the same day. The female parent of this cross was found in 1944 to be similar in ascorbic acid content to the Bounty variety.

A planting of approximately 200 *L. peruvianum* plants representing eight Bureau of Plant Industry introductions was made at Poamoho in the spring of 1945. Prior to transplanting the seedlings had been grown in a test bed heavily inoculated with the root knot nematode. Only plants without nematode galls were transplanted to the field. Twenty-five selections were made at maturity on the basis of plant vigor, fruit set, and fruit size. Representative fruit samples consisting of ten mature fruits of each selection were analyzed for ascorbic acid content.

The ascorbic acid content of the *L. peruvianum* selections ranged from 56.5 to 109.5 mg per 100 grams of fresh tissue. The values for Pearl Harbor grown under similar conditions but analyzed at an earlier time ranged from 8.5 to 19.5 mg.

Discussion

The evidence presented here proves the value of *L. peruvianum* as a parent in the development of a tomato variety resistant to nematodes. The possibility of developing a tomato high in vitamin C is also indicated; however, the high vitamin C content of selections from an interspecific cross between *L. esculentum* and *L. peruvianum* may be at least partially associated with the small size of the fruit. The cross sterility of *L. peruvianum* with *L. esculentum* has delayed progress, but the results both here and elsewhere indicate that the chances are excellent that this sterility problem can be overcome.

An analysis of successful interspecific crosses between *L. esculentum* and *L. peruvianum* indicates that the selection of parental varieties or strains within the two species is of importance. Porte and Walker (6) were successful in making an interspecific cross only when the Prince Borghese variety was used as the female parent. In the present study a derivative of a cross between *L. hirsutum* and *L. esculentum* proved most successful as the female parent. There is also good reason to believe that variation for compatibility with *L. esculentum* occurs within the *L. peruvianum* species. This is indicated by the high fertility of F_8 and later selections of a cross made by A. F. Yeager of the New Hampshire Experiment Station between the Michigan State Forcing variety and *L. peruvianum*. Comparable fertility has not been exhibited by crosses reported here or by Smith (9) who also used Michigan State Forcing as the female parent.

The application of the embryo culture technique has made it possible to grow to maturity embryoes which normally would have aborted. The possibility of improving the compatibility of *L. peruvianum* with the common tomato by doubling the chromosome number of one of the parents is suggested by the success of Cooper and Brink (3) with a cross between 4n *L. pimpinellifolium* and 2n *L. peruvianum*. A similar cross involving 2n *L. pimpinellifolium* as the female parent was unsuccessful.

None of the hybrids or selections described here are suitable for commercial use. The F_5 selections from the cross between Michigan State Forcing and *L. peruvianum* are the most advanced but still need improvement in both plant and fruit characters. Minor attention is

being given to the further improvement of these selections because it is felt that even though they possess tolerance to nematodes, the level of resistance is not sufficiently high to provide an ultimate satisfactory solution to the nematode resistance problem. These selections may possess factors for resistance which will prove valuable in combinations made with nematode resistant selections from other *L. peruvianum* hybrids.

An indication that resistance to nematodes is dominant and is controlled primarily by a relatively small number of factors is shown by the F_1 and F_2 data from a cross between a susceptible *L. hirsutum–L. esculentum* derivative and the resistant *L. peruvianum*. The F_1 was resistant and a high proportion of the F_2 segregates were in the resistant Classes 0 and 1. The moderate resistance of an F_1 hybrid between a *L. esculentum–L. pimpinellifolium–L. chilense* derivative and *L. peruvianum* suggests either a more complex inheritance or the heterozygosity of the *L. peruvianum* strain used in producing this hybrid.

The vitamin C content of the F_1 hybrid between the *L. hirsutum–L. esculentum* derivative and *L. peruvianum* was intermediate between the two parents. No conclusion can be drawn, however, regarding the mode of inheritance because a negative correlation has been demonstrated between fruit size and vitamin C content by Reynard and Kanapaux (7). The fruit size of this hybrid was about twice that of the male parent and about one-fourth that of the female parent.

The heterozygosity of the *L. peruvianum* species is shown by the variation between plants for plant and fruit characters, for vitamin C content, and for nematode resistance. This heterozygosity is perhaps maintained by insect cross-pollination since the flowers of this species have been observed to be very attractive to bees and other insects. Selection is being continued to obtain homozygous parental material.

Summary

Progress in incorporating root knot nematode resistance and the high vitamin C content of the wild tomato species *L. peruvianum* into a commercial variety is discussed.

A method of testing tomato seedlings for nematode resistance in an artificially inoculated test bed is described.

A successful embryo culture technique for securing hybrids between the cross sterile *L. esculentum* and *L. peruvianum* species and a description of hybrids obtained through the use of this technique are discussed.

Selections have been made which are superior to the commercial varieties both in nematode resistance and vitamin C content. The most resistant selections are cross sterile with *L. esculentum*. Cross fertile F_5 segregates of a cross between Michigan State Forcing and *L. peruvianum* lack sufficient nematode resistance to provide a solution to the problem.

Inheritance data indicate that resistance to nematodes is dominant to susceptibility.

The *L. peruvianum* species has been shown to be heterozygous for nematode resistance and vitamin C content.

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Breeding Tomatoes for Resistance to Spotted Wilt in Hawaii[1]

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Spotted wilt of tomato, the virus of which is identical with the yellow-spot virus of pineapple (7, 11), often causes plant losses of 75 to 100 per cent in tomato fields in Hawaii. Severe outbreaks may occur at any time of year, but are generally most frequent from spring to fall. It is believed that the most common host plant is a weed, *Emilia sonchifolia* (4). Onion thrips after feeding on virus-infected Emilia migrate to, and feed on, tomato plants, which then become diseased. Severity of outbreak of the disease cannot be easily predicted, resulting in the farmers' constant fear that his tomato crop may be destroyed. Chemical dusts and sprays used for thrips control have not thus far proved practical in Hawaii or elsewhere as a means of appreciably reducing losses from spotted wilt. While improved methods of thrips control may possibly in the future prove effective in reducing incidence of spotted wilt, it is nevertheless clear that the most desirable answer to the problem is the development of tomato varieties that do not contract the disease.

In the present paper a discussion of known sources of resistance in tomatoes, development in Hawaii of a test nursery, present status of resistant selections of commercial value, and data on inheritance will be given.

Sources of Resistance to Tomato Spotted Wilt

Strains of *Lycopersicon pimpinellifolium* have been reported to be resistant to spotted wilt by Samuel *et al.* (12), Wenholz (14) and Smith (13). Smith (13) also reported five strains of *L. peruvianum* to be resistant. BC–10, an F_6 selection of (133–6 x *L. pimpinellifolium*) x 133–6, developed at the California Agricultural Experiment Station was found in 1941 to be resistant to spotted wilt in Hawaii. Early work on development of BC–10 was done by D. R. Porter and subsequent work by M. W. Gardner. German Sugar, apparently of German origin and likely an *L. esculentum* x *L. pimpinellifolium* derivative, was also found in 1941 to be resistant to spotted wilt in Hawaii (2). The variety was secured from F. G. Krauss of Honolulu. It was subsequently found to be resistant to spotted wilt in California (13).

Several seed lots, of possible value for spotted wilt resistance, were received from Australia (H. Wenholz) in 1939, but plants proved susceptible in Hawaii (2). A tip-blight-resistant selection of Indiana Baltimore received from the Oregon Agricultural Experiment Station (F. C. Reimer) was also susceptible. The tip-blight disease has been described by Milbrath (5).

German Sugar, because of small fruit size and BC–10, because of unfruitfulness, were of no value as commercial varieties for Hawaii.

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Yet, since they were larger-fruited than *L. pimpinellifolium,* they were used almost exclusively as sources of resistance in the early hybridization program. It was soon found that selections from a cross of Bounty x BC–10 were superior to other materials in fruit size, fruit set, and general plant characters. One highly fruitful, spotted wilt-resistant selection from the cross was subsequently carried for nine generations and released under the name Pearl Harbor (3). Pearl Harbor is now being used widely as a parent in crosses in the tomato improvement program, not only for resistance to spotted wilt, but for its excellent fruit setting ability and unusually refined fruit characters. Principal weakness of the variety, other than susceptibility to other tomato diseases, is its medium fruit size.

Method of Testing for Spotted Wilt Resistance

The testing and elimination of spotted wilt susceptibles from large segregating populations of plants have been the most difficult phase of the breeding program. Because of the erratic occurrence of the disease in the field, elimination of susceptibles cannot be depended upon. Artificial inoculation has been difficult in Hawaii, although intensive work on this phase of the problem has not been carried out. It is felt that "natural" infection by thrips under outdoor conditions is desirable. It was therefore essential that an effort be made to develop a "nursery" that would not only provide a surer means of "natural" infection but also would make it possible to discard susceptible plants before they were planted to the field, thereby saving the heavy costs of large field plantings. Therefore, spotted wilt-infected Emilia was transplanted in an area approximately 100 x 75 feet, and fertilized and irrigated as required to maintain satisfactory growth. Emilia re-seeds easily, so that a year-round planting has been maintained at slight expense. Onion thrips are introduced into the nursery from such crops as bunching onions, cabbage, and edible pod peas. Bunching onions are grown in a separate area as an almost constant source of thrips, although low populations of the insect occur from time to time. Observation indicates that a high population of thrips on Emilia cannot be expected over extended periods. The major problem connected with the nursery has thus been a source of thrips. However, in some tests as high as 80 per cent of the seedlings of susceptible varieties of tomatoes have been eliminated in the nursery. In most tests, it has been possible to at least determine whether certain lines were highly susceptible or apparently homozygous resistant to spotted wilt. Such data are obviously useful in determining the relative desirability of proceeding further with individual selections.

For nursery tests seedlings are transplanted, about 10 days from time of sowing seed, to large pots (No. 10 can or one-gallon can). Five plants are transplanted to each pot. Usually 20 plants (4 pots) constitute the minimum number for a seed lot. Pots are replicated in random blocks in the nursery and are generally left there for 3 to 5 weeks. Symptoms of spotted wilt may appear in susceptible plants about 10 days after exposure. Infected plants, along with those having undesirable vine and fruit characters, are eliminated. Remaining plants are set

out either in tile beds or in the field for further observation and final selection.

Present Status of Spotted Wilt Resistant Selections

Further selection for large fruit size within the Pearl Harbor variety is being carried on, although it is not to be expected that distinctly large fruit types will appear. Testing of Pearl Harbor for resistance has also been continued. Table I gives a brief summary of the most

TABLE I—Comparison of Spotted Wilt Resistance of Pearl Harbor and Bounty Tomato Varieties

Varieties	Plots	Plants Observed	Plants Infected		Total Plants Observed	Total Plants Infected	
			Number	Per Cent		Number	Per Cent
Pearl Harbor..	Field plots*	5,297	28	0.5	6,396	37	0.6
	Test plots**	1,099	9	0.8			
Bounty.......	Field plots*	1,333	442	33.2	2,070	664	32.1
	Test plots**	737	222	30.1			

*These data are compilations from eight field tests in which infection occurred under natural conditions at Aiea, Poamoho and Waialua, Oahu.
**These data are compilations from eight tests in Emilia nursery.

recent data available on resistance. While many other susceptible varieties have been planted and tested along with Pearl Harbor their behavior does not vary greatly from that of Bounty; hence, it is not considered necessary to present detailed data in this paper. It is obvious, from Table I, that Pearl Harbor has maintained a very high level of resistance, as compared to Bounty, in both field and nursery.

In order to secure types with larger fruits than Pearl Harbor, several hundred crosses have been made with such varieties as Pritchard, Coopers Special, Grothens Globe, and Pearson. Backcrosses to Bounty as well as many double crosses, have also been made. Of 58 of the most promising F_2 and F_3 selections from these crosses, seven showed promise of good resistance, plus larger fruit size than Pearl Harbor. One of the most promising lines is HES 1383, selected from a cross of (Pearl Harbor x Bounty) x (Pearl Harbor x Pritchard). HES 1383 lines are now in the 6th generation; however, further testing and selection is necessary before it is determined whether early, large-fruited, high yielding, high quality, resistant types will be available for commercial usage. It is well known that it is extremely difficult to isolate tomato lines homozygous for distinct earliness, large fruit size, and of definitely high fruit quality (smoothness, depth, solidity), regardless of selection for disease resistance.

Inheritance of Resistance to Spotted Wilt

Resistance of the Pearl Harbor variety to spotted wilt is apparently due to a single dominant gene. In the spring of 1944, excellent field readings were obtained on F_2 progeny of susceptible x susceptible and resistant x susceptible varieties. In these readings, only those plants showing obvious stem necrosis were recorded as susceptible. No attempt was made to classify plants on the basis of milder symptoms, such

as ringspots on leaves. Classification was, therefore, based on symptoms similar to those described by Norris (6) as due to a necrotic strain of spotted wilt, and similar to those termed by Milbrath as tip blight (5). In this test, 392 out of 1315 or 29.8 per cent of F_2 plants of susceptible x susceptible crosses were diseased; 153 out of 2023, or 7.6 per cent of F_2 plants of resistant x susceptible crosses were infected. If calculated on the basis that 70.2 per cent (100–29.8) of susceptible plants escaped infection, the total number of plants theoretically susceptible in the resistant x susceptible progeny should have been 513 instead of 153. When the F_2 data, based on this logical assumption, were subjected to a test for goodness of fit, highly significant 3:1 ratios were obtained for progeny of each of the three crosses and, of course, for their combined progeny. These data are presented in Table II.

TABLE II—SEGREGATION FOR RESISTANCE TO SPOTTED WILT IN F_2 PROGENIES

Cross	Total No. of F_2 Plants Observed	Field Count	Calculated on the Basis of 70.2 Per Cent Having Escaped Infection	
		Diseased	Healthy	Diseased
		Susceptible × Susceptible F_2		
T 572 Pritchard × Bounty	565	176		
T 588 823 × Bounty	565	167		
T 706 Bounty × Oxheart	185	49		
Total	1,315	392	0	1,315
		Resistant × Susceptible F_2		
T 624 657* × Bounty	676	54		
T 704 657 × Pritchard	840	64		
T 629 657 × Pearson	507	35		
Total	2,023	153		
Observed			1,510	513
Calculated 3:1			1,517.25	505.75

*Subsequently released as the Pearl Harbor variety.

It has been observed time after time that F_1 plants of resistant x susceptible crosses are resistant to spotted wilt. It is possible to cross Pearl Harbor with a variety of distinctly larger fruit size, thereby improving upon size of the variety, possibly securing hybrid vigor and yet maintaining resistance to spotted wilt (1).

Data on backcrosses to susceptible varieties or data on large numbers of F_3 selections taken at random from resistant x susceptible crosses are not now available.

Neither Pearl Harbor nor F_1 progeny of the variety can be considered immune to spotted wilt (Table I). In general, however, infection has been less than 1 per cent in Hawaii. In Australia (8) and South Africa (9), it is interesting that the variety is reported to have little or no resistance, while in California resistance in some areas is considered of distinct commercial value (10). Many factors may conceivably be involved in accounting for such differences in spotted wilt resistance, such as virus strains, numbers of infective thrips, species of thrips (apparently only *Thrips tabaci* is present as a vector in Ha-

waii), climatic conditions, and host plants. "Mild," "ringspot," and "necrotic" strains of spotted wilt have been suggested by Norris (6). Little is known concerning the possible roles of the various listed factors other than that of Thrips tabaci.

It is not uncommon to find spotted wilt ringspots of varying size on leaflets of Pearl Harbor plants, yet the virus seems to remain localized, with no systemic invasion apparent. Young plants showing such spots when set in the field continue to develop normally. If it is true that the variety resists systemic invasion but not localized injury, it is easy to picture a situation in which large numbers of infective thrips attacking a plant would produce, in effect, systemic injury. Or it might be speculated that, following attack of large numbers of infective thrips, virus content of the plant is raised to a high level resulting in systemic injury. On the other hand, Pearl Harbor may be resistant in Hawaii to the severe strain (necrotic type causing stem necrosis) and susceptible to the mild or ringspot strain.

The difficulty that has been encountered in isolating early resistant lines of distinctly larger fruit size than Pearl Harbor, from progeny of crosses involving Pearl Harbor and large fruit types, may possibly involve a linkage problem. Since an answer to this question would require the recording of many physical measurements and since tests for susceptibility to spotted wilt in large plant populations have not thus far given complete elimination of susceptibles, it has not been practical to study linkage between resistance on the one hand and fruit size, fruit set and earliness on the other. It can be stated, however, that selections of considerable promise for large fruit size and resistance are now available.

Summary

Sources of resistance to tomato spotted wilt in Hawaii are discussed. Development of a nursery for year-round testing of tomato lines for resistance or susceptibility is described. A weed, *Emilia sonchifolia,* is used as a host plant in the nursery.

Additional data on Pearl Harbor, a heavy yielding variety with medium sized, refined fruits, which was released in Hawaii for resistance to the virus, are presented. Resistance of Pearl Harbor is apparently due to a single, dominant gene. Highly significant ratios of 3 resistant to 1 susceptible were obtained for F_2 progeny of crosses of resistant x susceptible lines. It is pointed out that such factors as climate, spotted wilt strains, and different hosts and vectors may possibly be found to alter this genetic behavior.

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Tomato Improvement in Hawaii[1]

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THE principal commercial varieties of tomatoes developed for the mainland of the United States, such as Marglobe, Rutgers and Pritchard, are not well adapted in Hawaii. In general, they develop large vines with few fruits.

Varieties developed in Louisiana, Puerto Rico and Florida were shown by Welch (23) to be the most promising for Hawaii, yet these later proved so susceptible to diseases such as spotted wilt, *Stemphylium solani*, and fusarium wilt that they were considered undesirable for commercial use, particularly at low elevations in the islands. In the spring of 1941 a tomato breeding porgram was initiated, the first objective being that of developing an early, spotted-wilt resistant tomato capable of setting fruit well at low elevations (13). With progress on this work, reported in a separate paper in the present proceedings (12), the improvement program was expanded to include breeding for resistance to *Stemphylium* (hereafter referred to as gray leaf spot), nematodes, mosaic (strains unknown), fusarium wilt and for high vitamin C content. Reports on gray leaf spot (10) and nematode resistance, as well as vitamin C content (15) are also included in these proceedings.

It is the purpose of the present paper to briefly outline the general organization of the project, to describe testing methods used, and to list the preliminary results of that phase of the project concerned with combined resistance to spotted wilt, gray leaf spot, and fusarium wilt.

ORGANIZATION OF TOMATO BREEDING PROGRAM

The Department of Vegetable Crops has major responsibility for hybridizing, testing and selecting of improved lines for disease resistance and superior vine and fruit characters; the Department of Plant Pathology has assumed responsibility for studies of the disease organisms; the Nutrition department has assumed responsibility for vitamin determinations.

In the hybridization program, several difficult breeding problems are involved. At the outset, the question arose as to whether lines resistant to individual diseases should be developed to advanced generations before complex crosses were made or whether, from the

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beginning, such complex crosses involving all known sources for resistance to the several diseases and for heavy yield and fruit quality should be made and subjected to the combined or successive attacks of spotted wilt, gray leaf spot, fusarium wilt, nematodes, and mosaic. The latter approach was impractical in part because of a lack of known mosaic resistant types and of nematode resistant types compatible with *L. esculentum*. Further, it was recognized that development of a line resistant to the several diseases would require more time than development of lines resistant to individual diseases. Resistance to even single diseases, under stress of war conditions, was of considerable importance. Therefore, department members were assigned subprojects for attaining definite goals of tomato improvement for single diseases, while the overall project leader assumed the responsibility of becoming familiar with germ plasm being used in each of the channels of improvement and, at the earliest possible time, made complex crosses involving combined resistance. It was logical that the sooner such complex crosses were made and the sooner their progeny was subjected to a sequence of tests to remove susceptibles, the more rapidly could desirable types carrying combined resistance be developed. Year round temperatures favorable for rapid growth and development of the tomato plant make Hawaii an excellent place for rapid progress in a breeding program. Under field conditions, at medium to low elevations, fusarium wilt, gray leaf spot, spotted wilt, nematodes, and mosaic may affect tomatoes at any time of the year. Fusarium attack depends, of course, on extent of soil contamination. Data secured by artificial testing for disease resistance is therefore supplemented by observations on natural infection in the field. Defoliation by *Alternaria solani* is frequently serious in the field also. Damage by *Septoria lycopersici* has been sporadic; *P. solanacearum* (bacterial wilt) has occasionally caused heavy losses.

Method of Testing for Combined Resistance

The approximate timing and sequence used at present in testing for fusarium wilt, spotted wilt, and gray leaf spot follows:

Step 1:—Fifty seeds of each lot are planted in 1-gallon cans filled with sterilized soil. Bottoms of cans are perforated to allow good drainage.

Step 2:—Approximately 10 to 15 days after seeds are planted, a suspension of gray leaf spot spores is sprayed over the young seedlings with an atomizer.

Step 3:—Plants are left in a humidity chamber approximately 48 hours.

Step 4:—Twenty-four to 72 hours after removal from the chamber, all plants showing gray leaf spot lesions on the cotyledons are removed. This gives essentially a cotyledon test. At the usual prevailing average daily temperatures of 75 to 80 degrees F, tomato seeds germinate and seedlings develop rapidly. The cotyledon test for gray leaf spot resistance appears to be satisfactory for eliminating susceptibles, since relatively few plants when thus tested and transplanted to the

field have developed the disease. Up to the present time gray leaf spot spores have been obtained from infected plants growing in the field.

If it is considered necessary to test the seedlings for gray leaf spot a second time before transplanting to the field, cans are again placed in the humidity chamber and plants are sprayed with a spore suspension.

Although testing for *Alternaria solani* (either leaf spot or collar rot phases of early blight) has not been carried on, in one combined test (C–9) leaves used for obtaining gray leaf spot spores showed an occasional early blight lesion and, while sufficient early blight spores were not present in the inoculum to interfere greatly with the gray leaf spot test, heavy infection of plants with collar rot was observed by the time plants were ready for field transplanting (Step 8). If it is desired to include early blight in the testing sequence, it may thus be practical to add the early blight spores to the gray leaf spot inoculum (Step 2). Perhaps septoria leaf spot spores could also be added.

Step 5:—After removal of gray leaf spot susceptibles, plants are allowed to harden off 4 to 8 days, then are removed from the gallon cans, the roots dipped in fusarium inoculum (250 cc of fusarium oat inoculum in 2000 cc water), and the seedlings immediately transplanted to gallon cans — five plants per can.

Step 6:—If the weather is dry and hot, cans are kept in the shade 2 to 5 days to reduce losses from shock, then cans are set in the spotted wilt nursery (12).

Step 7:—Plants are left in the spotted wilt nursery 3 to 4 weeks for fusarium and spotted wilt to eliminate the susceptibles. Once each week cans are irrigated with a nutrient solution (3 to 4 pounds of 11–48 ammonium phosphate in 50 gallons of water). Plants with weak central stems, leggy growth, and sparse foliage are eliminated. Since plants are left in the cans long enough for the first and second blossom clusters to appear, late plants and those showing long styles, small and/or rough fruits (from observation of ovary size and roughness) are also removed. If desired, indeterminate types are discarded. Thus, before plants are transplanted to the field, a relatively high percentage of the original population may be eliminated. Elimination of plants in young stages of growth for inferior vine and fruit characters was practiced by Yeager (24). The method used here extends the idea to include elimination for several diseases.

Step 8:—Remaining plants are transplanted either to tile beds or to the field. If soil in the beds or field is known not to be infected with fusarium, approximately one hundred cc. of fusarium oat inoculum (without water dilution) is placed around the roots of each plant at transplanting time — a method which has been used by Porte (19).

Up to the present time, testing for mosaic and nematode susceptibility has not been included in the combined resistance program. If promising lines are developed for resistance to mosaic and/or nematodes, such lines will be crossed with lines resistant to fusarium wilt, spotted wilt and gray leaf spot. It should be possible to include a test for nematodes, in the combined resistance program previously outlined by placing inoculum under the seed at time of planting (15), in

Step 1. In the same testing sequence inoculation with mosaic could be made early in Step 7.

It is to be expected that occasional changes will be made in methods of testing for combined resistance as more experience is gained and as more information on the disease organisms becomes available from plant pathologists.

Sources of Germ Plasm for Combined Disease Resistance

Original sources of resistance to spotted wilt, gray leaf spot, and nematodes are discussed in accompanying papers and need not be repeated here (10, 12, 15). Pan America (18) has been used for crosses involving fusarium resistance, as have also other lines from W. S. Porte, B. L. Wade and C. F. Andrus of the United States Department of Agriculture, and C. M. Tucker of Missouri. Material of possible value for mosaic resistance has been received from P. G. Smith and J. W. Lesley of California and S. P. Doolittle and W. S. Porte of the United States Department of Agriculture. Principal hope for mosaic resistance is being based on crosses between *L. chilense-L. esculentum* derivatives and *L. hirsutum-L. esculentum* derivatives, with the idea of combining, if possible, *L. chilense's* tendency to escape mosaic (11), with *L. hirsutum's* tolerance to mosaic (20). The mosaic resistance phase of the project is in early stages of development and will not be discussed further in this report.

Present Status of Combined Resistance Lines

Progeny of Complex Crosses:—In general, from 1000 to 3000 seedlings are run through each main combined resistance test. So far, a relatively small percentage of seedlings have survived the sequence of inoculations for disease and elimination for inferior vine and fruit characters. In test C7, 1030 seedlings were tested; of these, only 35 plants were selected for transplanting to tile beds; of the 35, six plants were finally selected for further tests. In test C8, 2158 seedlings were tested; of these, 219 were set in tile beds or in the field; of the 219, 61 plants were saved, many being F_3 selections.

Resistance to spotted wilt has been the most difficult factor to test for, with elimination of susceptibles well below that for gray leaf spot or fusarium wilt (Table I). Backcrosses to desirable spotted wilt resistant types are therefore being made, and the F_1 hybrids run through the gray leaf spot-fusarium-spotted wilt test. While it is noted in Table I that a few plants of Bounty and Pearl Harbor escaped infection with gray leaf spot, many tests have shown that 100 per cent of the plants of susceptible varieties are infected with the disease.

Several promising medium to large fruited lines have been selected for resistance to gray leaf spot, fusarium and spotted wilt. Most are F_2 or F_3 lines, and none have been homozygous resistant to the three diseases. However, some show high resistance to one or two of the diseases and at least heterozygous resistance to the other. In Table I, a few lines run through tests C7 and C8 are compared for three-way resistance.

TABLE I—RESISTANCE OF TOMATOES TO GRAY LEAF SPOT, SPOTTED WILT AND FUSARIUM WILT*

Line or Variety	Parentage	F	Test No.	Gray Leaf Spot			Fusarium Wilt			Spotted Wilt		
				Number Tested	Number Resistant	Number Susceptible	Number Tested	Number Resistant	Number Susceptible	Number Tested	Number Resistant	Number Susceptible
79532 (BPI, USDA)...	L. pimpinellifolium	–	C7	50	50	0	20	20	0	20	20	0
Pearl Harbor	———	9	C7	48	4	44	20	0	20	20	19	1
Bounty.....	———	–	C7	37	1	36	20	0	20	30	15	15
HES 1965	Complex	3	C7	33	33	0	21	15	6	21	17	4
C2	Pearl Harbor ×Pan America	1	C7	—	—	—	20	16	4	20	20	0
Pan America	———	–	C7	—	—	—	20	20	0	—	—	—
HES 1965—C7	Complex	4	C8	55	55	0	30	22	8	28	28	0
Pearl Harbor	———	9	C8	53	0	53	20	0	20	20	20	0
Bounty	———	–	C8	51	6	45	15	0	15	38	32	6
T-2455	Pritchard ×1965	1	C8	42	42	0	20	10	10	13	13	0

*79532, HES 1965, HES 1965-C7, and T-2455 were first tested for gray leaf spot, then a selected number, usually 20, of the same plants were tested for fusarium wilt and spotted wilt. If plants inoculated with fusarium wilt died early, they were not listed in the "Number tested" column for spotted wilt. Plants which showed any apparent degree of stunting due to fusarium wilt, accompanied by definite vascular discoloration, are listed as susceptible. Those with slight vascular discoloration and no apparent stunting are not included as susceptible. Separate lots of Pearl Harbor, Bounty, and Pan America were used for each indicated disease test. C2 was inoculated with fusarium wilt, then placed in the spotted wilt nursery.

HES 1965, an F_3 selection from a complex cross, with medium size fruits, showed promise of resistance to the three diseases (test C7). An F_4 selection from this line, HES 1965–C7, in a subsequent test (C8) continued to show promise. Lines with more desirable vine and fruit characters than HES 1965 are now under test. One of these lines, HES 2214, has been selected to serve as an example of the complex parentage of most of the promising selections now being carried (Fig. 1). Actually, resistance to the three diseases probably stems largely from *L. pimpinellifolium,* although the role of *L. peruvianum* may be important in this particular case. A *L. pimpinellifolium* (BPI Number 79532) line from the United States Department of Agriculture is highly resistant to the three diseases (Table I).

While large fruited, high quality, heavy yielding types homozygous for resistance to the three diseases have not yet been developed, the evidence so far indicates that such lines can be isolated. Inheritance of resistance to the individual diseases is given only incidental attention in combined resistance work since such data are more easily secured in other projects or have been reported previously by other investigators (1, 2, 3, 6, 10, 12, 22). While it may be possible to secure data on linkage between factors for disease resistance as a part of the combined resistance tests, without appreciable additional effort, and although it is recognized that a tomato improvement program depends to an important degree upon genetic data on the crop, it is nevertheless the first purpose of the project to place major emphasis on the final, practical goal of introduction of superior varieties.

F_1 Hybrids:—Since several workers (4, 5, 8, 9, 14, 16, 17, 21) have shown the value of F_1 hybrids for increasing the yielding ability of the tomato, and since resistance to such diseases as fusarium wilt (1, 6), spotted wilt (12), and gray leaf spot (10) may be highly domi-

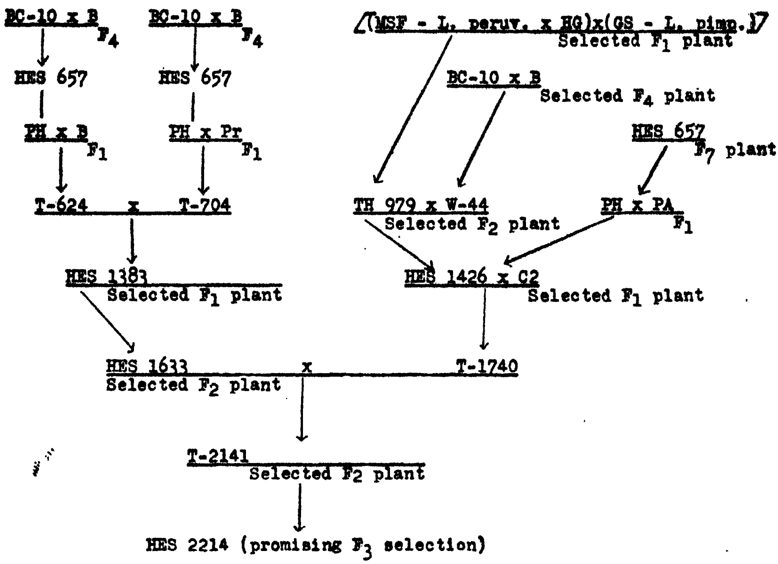

FIG. 1. This diagram shows the complex parentage typical of most lines now being developed for combined resistance to diseases in Hawaii. Key to abbreviations: B = Bounty; PH = Pearl Harbor; Pr = Pritchard; MSF = Michigan State Forcing; L. peruv. = L. Peruvianum; L. pimp. = L. pimpinellifolium; PA = Pan America; GS = German Sugar. The MSF — L. peruv cross used in this hybrid was made by R. Urata of the Hawaiian Sugar Planters' Association. The other crosses were made at the Hawaii station.

nant, the question arose as to whether F_1 hybrids could be utilized in Hawaii not only to increase yields, but to combat diseases. With Pan America available for fusarium resistance, it was logical, after the development of Pearl Harbor (13), to test the F_1 hybrid of the two for resistance to both fusarium and spotted wilt. The F_1, designated as C_2, was found to be resistant to the two diseases (Table I), but it was relatively late and not highly productive. Among numerous F_1 combinations made in connection with the entire tomato breeding program, it was observed repeatedly that the cross of Pearl Harbor x Pritchard was unusually productive. Sufficient seed of the F_1 was obtained for tests, in cooperation with the Agricultural Extension Service, on farms throughout the Territory. The hybrid, designated as C_1, yielded on an average at least 20 per cent more than varieties such as Bounty and Pearl Harbor (7). In addition to its heavy yielding ability, it was highly resistant to spotted wilt. It is interesting that Currence, Larson and Virta (9) suggested that Pritchard may have exceptional value as a parent in F_1 hybrids.

Although C_1 has resistance to spotted wilt and is very productive, the greatest benefit from an F_1 hybrid for Hawaii will be derived when resistance to *several* diseases is combined with heavy yielding ability.

SUMMARY

The organization of a project for improvement of tomatoes in Hawaii is described.

Time and sequence of testing of plants for combined resistance to spotted wilt, gray leaf spot, and fusarium wilt are outlined. Elimination of plants for inferior vine and fruit characters is also done before plants are set in the field. Possibility of including tests for nematode, mosaic, early blight and septoria leaf spot resistance in the same program is indicated.

Lines segregating for resistance to spotted wilt, gray leaf spot and fusarium wilt have been selected and tested. The possibility of securing resistance to the three diseases in a single line appears excellent. Large numbers of F_3 selections are now under test.

With the development of large fruited, high quality lines resistant to diseases, possibilities arise for use of F_1 hybrid seed for disease resistance and heavy yield. Preliminary results with such hybrids are discussed.

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Further Investigations on the Value of "Hormone" Sprays and Dusts for Green Bush Snap Beans[1]

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SNAP beans are frequently grown under environmental conditions not favorable for an optimal set of pods. Under such conditions bud abscission and blossom-drop have long presented a real problem in the growing of this crop. The failure of pods to develop limits successful commercial production, in certain geographical areas, to definite seasons of the year.

The use of growth-regulating substances ("hormones") for improving the pod-set and yield of beans has been investigated during the past 5 years at the Missouri Experiment Station. The results of initial studies have already been summarized and reported (5). These first trials demonstrated that under some environmental conditions beneficial results can be realized, while under others the effect was negative. A summary of these studies indicated that often the "hormone" sprays did not overcome sufficiently unfavorable effects of weather and that their use was costly due to the number of applications required. They were not recommended for general practice. In these first experiments α-naphthaleneacetic acid (NA), β-naphthoxyacetic acid (NOA), and β-indolebutyric acid (IBA) were tested. The chemicals were applied in water sprays at various concentrations. Several applications at 2 to 5 days intervals were made during the period of bloom.

More recently a number of substituted phenoxy and benzoic acids have been synthesized and many of their properties as growth substances determined by Zimmerman and associates (8, 9). Some of these newer "synthetic hormones" have been found particularly effective for fruit setting and for increasing the size of greenhouse-grown tomatoes (6, 7). This paper reports results obtained from spray and dust applications of para-chlorophenoxyacetic acid (ClPA) and other related "hormones" on green bush snap beans grown during the seasons of 1944 and 1945 at or near Columbia in central Missouri.

MATERIALS AND METHODS

Except for a few preliminary tests to determine concentration ranges, all experiments were conducted under field conditions and on a large scale. Treatments were replicated three, four, or six times as rows either 40 or 80 feet in length. Plants in the rows were carefully thinned to a definite number per linear distance. The soil consisted of a heavy clay or silt loam especially selected for its uniformity. Supplementary plant food was added at the rate of 600 pounds per acre of 4:12:4 mixed fertilizer.

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Spray applications were made by means of a barrow hand pump sprayer with a pressure maintained at 90 ± 20 pounds. The "hormone" chemicals were first dissolved in a small amount of alcohol and then diluted with water to the proper concentration. Spraying was usually done in the morning by thoroughly wetting the entire plant. Applications were made at the rate of 100 to 125 gallons per acre.

The hormone dust mixtures were prepared by dissolving and diluting the required chemical in a volume of ethyl alcohol sufficient to wet a given quantity of dust. The alcohol was allowed to evaporate leaving the hormone uniformly dispersed through the medium. Pyrax ABB, a pyrophyllite talc, was the standard diluent base used in all trials. The rate of dust application was 50 to 75 pounds per acre put on by means of small hand dusters. Application was always in the early morning at which time air movement was at a minimum and the foliage was covered with dew. All hormone treatments, whether in spray or dust form, were timed so that the initial application was 3 to 5 days following the appearance of the first flowers.

THE 1944 EXPERIMENTS

The spring bean crop was planted May 20, using seed of a commercial strain of the variety, Stringless Green Pod. The weather during the following two months was unusually hot and dry, and a great deal of supplementary water in the form of furrow irrigation was necessary. The plants were sprayed for the first time on June 22, and at weekly intervals thereafter, making a total of five applications. Particular attention was paid to meteorological conditions, during this period. The seven days following the first hormone treatment were characterized by a mean maximum temperature of 98 ± 3 degrees F, which was 9 degrees above normal. The mean maximum temperature for the 28 days during which the plants were sprayed was 5 degrees above average for this season. Only .26 inches of precipitation was recorded in the same 28 days.

The effects of the para-chlorophenoxyacetic acid (CLPA) treatments were evident within 5 to 7 days after the first spray application. The flower parts appeared more prominent, the foliage greener, and pod-set was noticeably increased (Fig. 1). The hormone treatments, the resulting yields, and the percentage increases over the controls are listed in Table I. The relative volume of pods harvested in the five pickings from the various treatments is shown in Fig. 2. It is to be noted that the increase, nearly 300 per cent over the controls, was remarkable in the first three pickings with the ClPA treatments. When the total crop is considered the highest yield group, ClPA, at a concentration of two parts per million, gave a 40 per cent increase in weight of pods. Though β-naphthoxyacetic acid (NOA) gave a noticeable yield increase in the first three and even the first four pickings, a decrease in total production resulted when the entire crop was considered. The concentration of NOA used in this experiment (*i. e.*, 10 parts per million) was that which proved most effective in previous studies (5). The increased yield from the ClPA treatments was due to a greater set of pods, but pod size and seed number were decreased

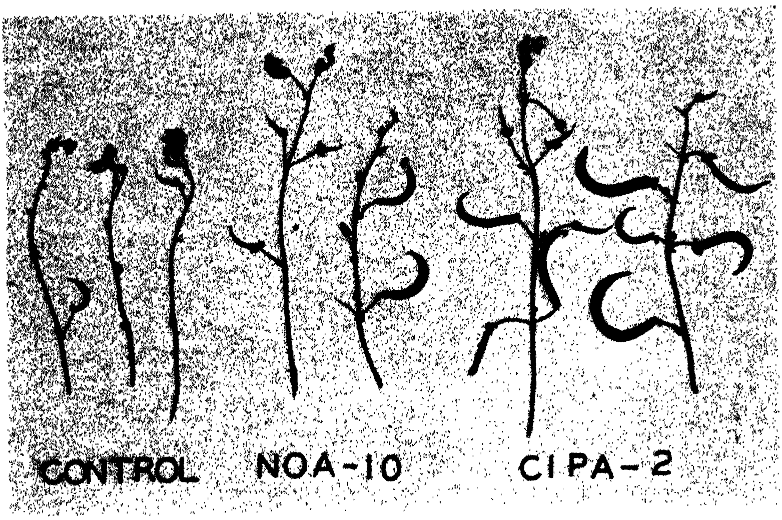

FIG. 1. Comparative set of pods and their development as affected by hormone sprays during hot, dry weather. The figures indicate parts per million of chemical used.

conspicuously. This was somewhat true of the fourth and especially of the fifth pickings, the pods from the first three harvests being quite normal. Many specimens, though filled out and otherwise normal, in the last two pickings were seedless or nearly so. This condition was most marked with the highest concentration of ClPA used, although it occurred in the other treatments and in the controls to a lesser degree.

The results from this experiment were encouraging. Para-chlorophenoxyacetic acid as a "bean hormone" seemed promising. However, it was realized that the crop was grown under abnormal environmental

TABLE I—EFFECTS OF HORMONE SPRAYS ON YIELD OF BEANS, MID-SUMMER CROP, MAY 20 TO AUGUST 3, 1944

Sprays Used*	Weight of Pods in Grams Per 500 Plants			Per Cent Increase or Decrease in Yield Due to Treatment			Averages for Total Crop	
	1st 3 Pickings	1st 4 Pickings	Total Crop 5 Pickings	1st 3 Pickings	1st 4 Pickings	Total Crop 5 Pickings	Weight Per Pod (Grams)	Number of Seed Per Pod
Tap Water (Controls)	2,354	7,980	14,704	———	———	———	4.35	2.13
NOA,** 10 ppm	3,181	9,066	13,996	+35.13	+13.48	−4.81	3.95	1.59
ClPA,† 5 ppm	8,770	13,679	16,860	+272.56	+71.22	+14.66	2.86	0.37
ClPA, 2 ppm	8,686	14,968	20,649	+269.00	+87.36	+40.43	3.20	0.59
ClPA, 1 ppm	7,560	15,296	18,604	+221.15	+91.46	+26.52	3.02	0.85

*Five sprays applied during flowering at intervals of one week
**NOA = β-Naphthoxyacetic acid.
†ClPA = Para-Chlorophenoxyacetic acid.

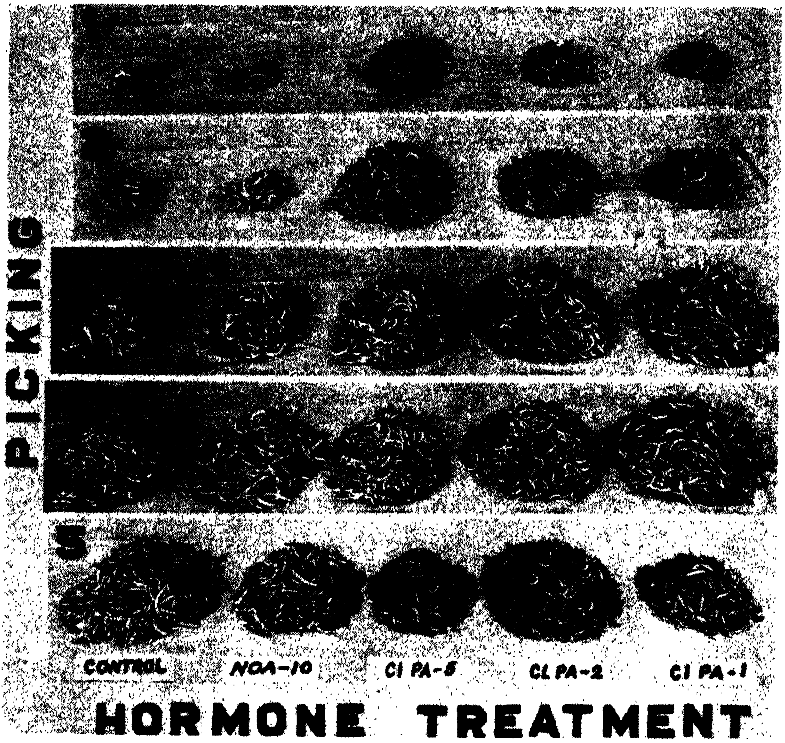

FIG. 2. Comparative bean yields as affected by hormone sprays in five successive pickings during hot, dry weather.

conditions — temperatures were high, rainfall was practically nil, and flowering as well as harvesting were prolonged over a 4-week period. The over-all total yields even with the hormone treatment were rather low. Accordingly a late summer as well as a fall crop were planted the same season. The respective treatments with the yields resulting therefrom are given in Tables II and III. The first planting (July 29 to September 29) matured under growing conditions near normal for that season of the year with a mean maximum daily temperature during flowering of 80 ± 7 degrees F. A heavy yield of beans resulted. It should be emphasized that only two spray applications were made on this crop. The resulting yields were 22 per cent above the controls where ClPA was used at the rate of one part per million. This increase could be in part attributed to larger pods (Table II). In the fall crop (August 3 to October 14) two additional "hormones" were tested, α-ortho-chlorophenoxypropionic acid (ClPP) and 2,4-dichlorophenoxyacetic acid (Cl_2PA). Yield increases were again significant from the "hormone" treatments, although total production was generally lower, because of colder weather and a light frost in early October. Increased yields in this instance also were traceable to a larger pod size (Table III). A favorable response from the use of para-

TABLE II—EFFECTS OF HORMONE SPRAYS ON YIELD OF BEANS, LATE SUMMER CROPS, JULY 28 TO SEPTEMBER 29, 1944

Sprays Used*	Weight of Pods in Grams Per 500 Plants (Total Crop)	Per Cent Increase or Decrease in Yield Due to Treatment	Averages for Total Crop	
			Weight Per Pod (Grams)	Number of Seeds Per Pod
Tap Water (Controls)	35,925	———	5.98	4.72
ClPA, 5 ppm	38,845	+8.13	6.60	4.70
ClPA, 2 ppm	40,390	+12.43	6.35	4.95
ClPA, 1 ppm	44,015	+22.51	6.54	5.16
ClPA, ½ ppm	40,380	+12.40	6.28	5.82

*Two sprays applied during flowering at an interval of ten days.

chlorophenoxyacetic acid (ClPA) under optimal growing conditions was thus demonstrated. The two additional new materials, 2,4-dichlorophenoxyacetic acid (Cl_2PA) and α-ortho-chlorophenoxypropionic acid (ClPP) also showed promise. A negative influence resulting from the use of β-naphthoxyacetic acid (NOA) in cool weather was in agreement with a previous report (5). In this crop, as well as in the preceding one, it should be emphasized that the pods produced by "hormone" treated plants were comparable in market quality to those produced by control plants. Staff members of the Department of Horticulture of the University of Missouri, judged them to be somewhat superior to the control in general appearance, color, size, and shape.

TABLE III—EFFECTS OF HORMONE SPRAYS ON YIELDS OF BEANS, FALL CROP, AUGUST 3 TO OCTOBER 14, 1944

Sprays Used*	Weight of Pods Per 500 Plants (Grams) (Total Crop)	Per Cent Increase or Decrease in Yield Due to Treatment	Averages for Total Crop	
			Weight Per Pod (Grams)	Number of Seeds Per Pod
Tap Water (Controls)	12,335	———	3.63	3.22
NOA, 10 ppm	11,581	−6.11	3.85	3.06
ClPP,** 5 ppm	11,728	−4.92	4.22	3.07
ClPP, 2 ppm	12,596	+2.12	3.72	2.86
Cl_2PA, †1 ppm	14,268	+15.67	4.05	3.15
ClPA, 5 ppm	13,788	+11.78	4.09	2.20
ClPA, 2 ppm	14,639	+18.68	4.14	2.98
ClPA, 1 ppm	12,365	+0.24	3.64	2.82

*Two sprays applied during flowering at an interval of one week.
**ClPP = α-Ortho-Chlorophenoxypropionic acid.
†Cl_2PA = 2,4-Dichlorophenoxyacetic acid.

THE 1945 EXPERIMENTS

Though rather conclusive evidence was obtained the previous season (1944) that para-chlorophenoxyacetic acid (ClPA) increased significantly the set and yield of green bush snap beans, the investigators felt that such results should be verified by another season's study. Since dusting is a more commonly adopted practice for insect control in bean production than is spraying, various concentrations of the hormone were incorporated into dusts. Some of these preparations were commercial mixtures containing rotenone, cryolite, and DDT, recommended for the control of bean leaf beetles (*Cerotoma trifurcata*). *Preliminary greenhouse and field trials demonstrated that both hor-*

mone and insecticide when combined together in a dust retained their specific effects. This is in accord with the work of Allen and Fisher in Wisconsin (1). To avoid the complicating effects of variable insect control on yields, talc (Pyrax ABB) was used as the diluent for all hormone dusts applied in comparative field tests.

The effects of four "hormone" chemicals applied in various concentrations on the yield of two varieties of green snap beans are given in Table IV. The dust in each case was put on at the approximate rate of 50 pounds per acre in each of two applications. Dusting was performed at an interval of 8 days covering the period of full bloom. The most effective ranges of concentrations from these records appeared to be about 25 parts per million for ClPA, 10 parts per million or less for ClPP and 50 parts per million or less for NOA. The optimal concentration range for Cl_2PA was not adequately determined. Yields generally were high. Growing conditions were favorable with a daily mean maximum temperature of 87 ± 3 degrees F for the 12 days of flowering. The magnitude of increase resulting from the use of hormone dusts compared favorably with that in the preceding year from sprays under similar growing conditions.

TABLE IV—COMPARATIVE EFFECTS OF DIFFERENT GROWTH-REGULATING SUBSTANCES APPLIED AS DUSTS ON THE YIELD OF GREEN SNAP BEANS, SUMMER CROP, JULY 5 TO SEPTEMBER 4, 1945

Hormone Treatments	Variety			
	Tendergreen		Stringless Green Pod	
	Weight of Pods Harvested Per 500 Plants. (Grams)	Increase or Decrease Due to Treatment (Per Cent)	Weight of Pods Harvested Per 500 Plants (Grams)	Increase or Decrease Due to Treatment (Per Cent)
Controls (talc only)	26,308	—	31,320	—
ClPA, 10 ppm	30,434	+15.7	—	—
ClPA, 25 ppm	33,870	+28.7	—	—
ClPA, 50 ppm	29,962	+13.9	34,234	+ 9.3
ClPA, 75 ppm	27,666	+ 5.2	—	—
ClPA, 100 ppm	25,658	- 2.5	—	—
ClPP, 10 ppm	33,142	+26.0	—	—
ClPP, 25 ppm	—	—	35,166	+12.3
ClPP, 50 ppm	22,936	12-.8	—	—
Cl_2PA, 25 ppm	—	—	36,696	+17.2
NOA, 50 ppm	29,256	+11.2	—	—
NOA, 100 ppm	—	—	31,744	+1.4
NOA, 200 ppm	24,792	-5.8	—	—

A second crop consisting of four leading varieties of snap beans was planted July 14. For this experiment — more elaborately planned than any previous one — a plot of uniform silt loam soil was selected at the Turner Horticultural Experiment Station, near Columbia. Three hormone treatments with adequate controls were used consisting of one spray and two dusts of para-chlorophenoxyacetic acid (ClPA). Treatments were replicated three times with each of the four varieties. The vines made good growth and produced an excellent crop of high quality pods. Daily mean maximum temperatures were 89 ± 4 degrees during flowering. *In this final experiment only one dust or one spray application was made.* These were applied 3 to 5 days fol-

lowing the appearance of the first flowers. In each case an increase in yield due to hormone treatment resulted (Table V). With each variety the treated groups consistently out-yielded the controls. According to the table, however, these differences were statistically significant with only the two varieties, Stringless Green Pod and Stringless Black Valentine. The yield variations which occurred in the control replications of Tendergreen and Tenderpod accounted in a large part for the failure of the difference in these varieties to show statistical significance. In general it would appear that hormone dust applications are equal in effectiveness to sprays. Under favorable growing conditions conducive to moderately high yields, all varieties gave an increase in acre production of 40–45 bushels of marketable pods above control treatments.

TABLE V—Effects of Para-Chlorophenoxyacetic Acid Applied in Sprays and Dusts on the Yield of Four Varieties of Green Snap Beans, Fall Crop, July 14 to October 12, 1945

Treatments (One Application Only, at Full Bloom)	Variety			
	Stringless Green Pod	Tender-green	Tenderpod	Stringless Black Valentine
Controls (Talc Only)				
Mean yield in bushels/acre†	178.4	142.5	246.3	192.8
ClPA, 2 ppm in Water Solution—Foliage Thoroughly Wetted				
Mean yield in bushels/acre	224.3	164.1	252.6	236.7
Difference or yield increase	45.9*	21.6	6.3	43.9**
Standard error of difference	10.3	9.7	43.2	1.8
ClPA, 25 ppm in Talc Dust—At Rate of 50 Pounds Dust/Acre				
Mean yield in bushels/acre	211.5	158.0	291.3	224.9
Difference or yield increase	33.1*	15.5	45.0	32.1*
Standard error of difference	7.4	16.6	41.7	5.1
ClPA, 50 ppm in Talc Dust—At Rate of 50 Pounds Dust/Acre				
Mean yield in bushels/acre	197.8	162.8	288.9	232.9
Difference or yield increase	19.4	20.3	42.6	40.1**
Standard error of difference	8.9	10.7	42.4	3.0

*Significant (.05).
**Highly significant (.01).
†Each value represents the average yield of three replications.

Discussion and Summary

Some of the recently introduced plant "hormones" of the substituted phenoxy acid group have given consistent yield increases when used as blossom sprays or dusts on green bush snap beans grown in Central Missouri. Of the chemicals tested para-chlorophenoxyacetic (ClPA) appears the most promising. Other related and effective chemicals are 2,4-dichlorophenoxyacetic acid (ClPA) and a-ortho-chlorophenoxypropionic acid (ClPP). The latter material has the merit of not modifying the foliage when used at concentrations above the optimum. Other of the hormone chemicals, β-naphthoxyacetic acid, a-naphthaleneacetic acid, and β-indolebutyric acid have been given adequate trial but not found consistently effective. In fact, instances of a depression in fruit set and yield have been recorded. This

latter effect, particularly of *a*-naphthaleneacetic acid applied as a blossom spray has been utilized in recent thinning experiments with apples (2).

The effectiveness of "hormones" on beans is determined to a large extent by weather conditions prevailing during the normally short interval of flowering and pod-formation. Hot-dry days with maximum temperatures above 90 or 95 degrees F are conducive to poor set in Missouri. Under such environmental conditions the application of an effective "hormone" tends to offset, in part, the unfavorable effects of weather. The normal processes which function in pod and seed formation seem to be supplemented. Consequently, the number of pods formed and the resulting yields are increased, at times to a marked degree. The most striking results from "hormone" treatment can be expected under unfavorable weather conditions normally conducive to poor set and low yields.

But even under more favorable weather conditions when flowering and pod development is normal, "hormones" have consistently given yield increases of 10 to 25 per cent (Tables II, III, IV and V), most of which can be attributed to a gain in size of pods. Not only was the mean weight per pod increased, but in some instances the length and the number of seeds as well. It would appear from a summary of the 2 years results reported, herein, as well as those of the preceding 3 years (5), that the specific effects of "hormones" may be diverse and to some degree unpredictable depending on prevailing seasonal differences.

A hastening of maturity has repeatedly been observed. There is also a marked tendency following hormone treatment for all of the pods to mature at more or less the same time, thus shortening the harvest period. When earliness and picking economy are factors, this item deserves consideration. It should also be emphasized in making yield comparisons that the entire crop be considered. A heavy yield during the first picking on treated vines may be compensated in part by greater yields on the controls in later harvests. A restricted comparison of only the first, or the first two pickings may grossly over-emphasize the "hormone" effects.

The most desirable concentration of para-chlorophenoxyacetic acid (ClPA) used as a spray in water solution has been fairly well established for our conditions. It is two parts per million. Applied as a spray which will thoroughly wet the plant, ClPA may be expected to give favorable results.

Dusts may be more practical and economical than liquid sprays as carriers of hormone chemicals. Our results, as well as those of Marth, Batjer and Moon (4) indicate that dust carriers are equally if not more effective. Snap beans are generally treated with an insecticide during or following full bloom. Since the "hormones" are compatible with commonly employed insecticidal dusts, the two materials can be combined, and thus an additional field or garden operation avoided.

The most effective concentration of hormone in the dust will depend largely on the quantity to be applied for insect control. Rates of dust application vary considerably depending on the insecticide and

its efficiency in controlling bean beetles. When about 50 pounds of dust is applied per acre, 25 parts per million of ClPA appears optimal. Obviously, this concentration would have to be adjusted upwards if only 5 pounds per acre were dusted on. In our studies where maximum yield increases were realized with C1PA, the net amount of hormone applied in one treatment, whether as a spray or dust, was equivalent to approximately 1 gram of the pure chemical per acre. Such a figure might serve as a basis for adjusting concentrations with rates of application. It must be emphasized that a concentration above that recommended may have very undesirable formative and modifying effects on the foliage and pods, and decrease rather than increase yields.

Bean pods from hormone treated plants, though usually of a darker green color, were comparable in composition to those produced on control plots. The total nitrogen content was found about equal. Pods from treated vines were slightly higher in their content of vitamin C. The market quality of the pods from treated plots was perhaps a little superior in that they were generally more uniform, better filled, and larger in size.

The "hormones" herein discussed have been thoroughly tested by us only on green bush snap beans. Our studies have indicated that they are not effective on peas, lima beans, or dry shell beans. This is in agreement with the work of Hardenburg (3). The hormone effect, which increases the yield of snap beans and which seemingly results from a growth stimulation of ovarian tissue, has also been observed generally to depress rather than stimulate seed formation and development. Accordingly, yield increases are not likely to be so marked with those crops wherein seeds make up the yield.

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Breeding Tomatoes for Resistance to Gray Leaf Spot in Hawaii[1]

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AT THE present time, gray leaf spot, caused by *Stemphylium solani* Weber (3, 4), is one of the most widespread and highly destructive defoliation diseases of tomatoes in Hawaii. Although it did not attract attention of Experiment Station workers before 1941, evidence accumulated from local farmers points to its having been of importance for several years prior to that time. Under the warm, humid climate of the islands, it extracts tremendous annual tolls from the tomato industry. Such tolls may be in the nature of reduced yields through defoliation of plants in unsprayed fields or of great expense in labor and materials required for a satisfactory control program.

Soon after America's entry into the war, the supply of suitable fungicides, upon which a successful control program depended, was largely shut off. Local stocks were rapidly exhausted and defoliation diseases had free reign. Coming at a time when shipping space was allotted to the importation of bare essentials and when fresh foods were so sorely needed, the tomato industry could ill afford to sustain such serious losses. Consequently, to the already active project at the Hawaii Agricultural Experiment Station for improving tomatoes for the Territory a subproject, designed for the breeding of gray leaf spot resistant varieties, was added. Following is a brief discussion of the efforts and progress made in the pursuit of this goal.

MATERIAL

The possibility of successfully breeding a commercial tomato variety that could withstand defoliation by S. solani was suggested by preliminary work done by Andrus, Reynard, and Wade (1) at the U. S. Vegetable Breeding Laboratory, Charleston, South Carolina. Testing numerous commercially established varieties, non-commercial lines, foreign introductions, and interspecific crosses under field and controlled greenhouse conditions they demonstrated that while all of their commercial lines and large-fruited *Lycopersicon pimpinellifolium* x *L. esculentum* segregates were susceptible, a high level of resistance was to be found in certain selections of L. pimpinellifolium and intermediate or small-fruited L. pimpinellifolium x L. esculentum segregates.

During the spring of 1943, samples of several of these lines containing possible resistance to gray leaf spot were secured and added to two collections of native L. pimpinellifolium (Waimea Cherry, pink, and Hamakua Cherry, red) in initial plantings at University Farm, Honolulu, and Poamoho substation, north Oahu. At the first location

[1]Published by permission of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 138.

defoliation by *S. solani*, encouraged by frequent valley showers, is generally severe throughout the year while at the latter heavy infestations are usually associated with the cooler, more moist seasons of the year. In these plantings, however, defoliation was equally severe and afforded an opportunity for observing the reaction of the various lines to natural development of the disease. Three lines, 42–8, 42–19 (received from the U.S.D.A. Vegetable Breeding Laboratory, Charleston, South Carolina), and P.I. 79532, received from the Ohio Experiment Station were outstanding in these and subsequent tests and were consequently used freely in crosses with standard varieties. The source of resistance in many of the present day advanced Hawaii Station selections may be traced to these small-fruited introductions.

In the following year, 1944, five additional introductions were received from the Experiment Station of the Hawaiian Sugar Planters' Association and were included in subsequent plantings. These latter were complex hybrids, involving three species of *Lycopersicon* in the parentage, and produced fruits of intermediate size. Their resistance to *S. solani* was outstanding in both field and greenhouse tests.

Methods of Testing

Seedling lots, in original trials, were planted and attended in the same manner as those of commercial plantings. To eliminate the possibility of dry weather preventing natural infection, an overhead irrigation system was installed to provide conditions conducive to rapid disease development. This was found to involve considerable time and effort as well as space for growing plants. Additionally, disease readings were not always conclusive. Frequently early blight, late blight, and septoriose prohibited accurate determinations of the incidence of gray leaf spot. In following tests, therefore, a method of greenhouse inoculation was employed as an aid in eliminating susceptible individuals. In its overall aspects, the technique was essentially the same as that described by Andrus *et al.* (1). It was modified in these tests to suit local needs and involved testing 50 to 100 seedlings of each hybrid or advanced selection considered as possibly containing resistant types. At about 10 days after emergence, the seedlings were transplanted to 4-inch clay pots or size 2½ tin cans where they were held until a height of about 9 inches was attained. At that stage, usually 25 to 30 days from date of planting, they were transported intact to outside benches or tile beds, sprayed with Stemphylium mycelial particles suspended in distilled water, incubated 2 days under a muslin frame (Fig. 1) and examined 3 days later.

In the inoculation process, culture 419, a single-spore isolate of the Stemphylium organism was consistently used. Seeded on potato-dextrose broth in 125 cc Erlenmeyer flasks and held at room temperature, the fungus colony generally covered the surface of the medium within approximately 3 weeks. At the time of using, the mats were removed, relieved of their excess moisture by blotting momentarily on cheese cloth, and placed in distilled water in a mechanical liquifier (Waring Blendor). By adjusting the richness of the inoculum after fragmentation to 100 grams of mycelium per liter of water and spray-

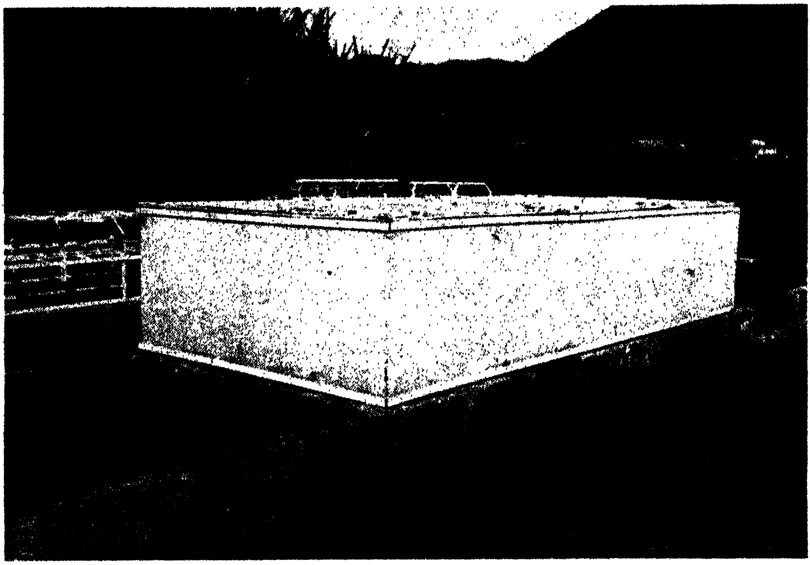

FIG. 1. Muslin frames used as incubators in controlled inoculation experiments. Frames measure 2 x 4½ x 10 feet and provide coverage for approximately 1,000 plants. Frequently several such frames were employed simultaneously.

ing on tomato plants just prior to incubation, severe infection was regularly obtained on susceptible plants.

The relative humidity surrounding the plants while in incubation was maintained at a suitable level by a fog-producing device erected outside and above the frame in a manner that permitted a fine mist to settle over the enclosure. Several such incubators were frequently employed simultaneously to accommodate the thousands of seedlings it was necessary to test for individual experiments.

On the third day after removal of the cloth covering, individual seedlings were examined and their reaction recorded. In segregating populations, reaction generally varied from apparent immunity to an outright killing of the very susceptible segregates. Between these limits all intermediate degrees of infection were seen. While seedlings coming through inoculation tests with but scattered lesions have in many cases resisted defoliation when carried to field plantings, it was nonetheless customary in these investigations to save for further propagation only the plants showing a complete absence of definite lesions.

RESISTANCE OF SOME ADVANCED SELECTIONS

From the time the first resistant introductions were observed in 1943, five major field plantings have been carried through at Poamoho substation in which individual plants were observed for commercial possibilities. Usually, each planting comprised approximately 1,000 plants representing approximately 50 to 60 line hybrids and selections.

Each trial was made up of seedlings possessing a high degree of resistance as determined by controlled methods of testing. The number of seedlings planted in each field trial represented the total number of resistant segregates coming from about 4,000 seedlings tested.

In each generation or field planting of the hybrid selections, careful examinations of individual plants were conducted at the time of heaviest flower production and at fruit maturity to eliminate plants of poor vine or fruit type. Those plants combining factors for heavy setting ability, extreme vine vigor, earliness, or other desirable characters were marked for further observation and selections.

In a planting completed in the spring of 1945, 80 advanced hybrid plants were marked as offering outstanding promise. These were further examined and given a rating in accordance with their relative value. Seed lots of the 23 selections receiving the highest score were planted and tested in greenhouse operations in preparation for the next field trial.

Resistance data on the progenies of these selections as secured in the artificial inoculation procedure already described, are presented in Table I. Six of the 23 selections were homozygous resistant while the.

TABLE I—REACTION OF THE PROGENY OF 23 PROMISING HYBRID SELECTIONS AND THREE COMMERCIAL VARIETIES TO *Stemphylium solani* UNDER CONDITIONS OF ARTIFICIAL INOCULATION

Selection	Parentage	Total Number Plants Tested	Per Cent of Progeny in Each Disease Class*		
			1*	2*	3*
HES 1881....	1591 = TH1178 (TH 979 × W44)	40	100	0	0
HES 1882....	T1683 = 1430 (TH1178) × 1199	97	42	44	14
HES 1883....	T1623 = 1410 (823 – Bounty × Pritchard 79532)	85	54	38	8
HES 1884 ...	1601 = 1428 (TH1178)	41	100	0	0
HES 1885....	1578 = 1432 (657 × 523 42.19)	40	100	0	0
HES 1887....	T1470 = 1624 (TH1177) × C2(657 × PA)	78	49	37	14
HES 1914....	1588 = 1426 (TH1177)	40	100	0	0
HES 1916....	T1684 = 1430 (TH1178) × 1199	44	61	39	0
HES 1927....	T1092 = TH1177 × T883	61	69	31	0
HES 1930....	T1693 = 1432 (657 × 523–42.19) × 1191	37	68	24	8
HES 1931....	1562 = 657- B × B–42.8 × 917	56	100	0	0
HES 1934...	T1554 = 1430 (TH1178) × 1347	96	42	45	13
HES 1938 ...	T1740 = 1426 (TH1177) × C2 (657 × PA)	66	61	33	6
HES 1939....	T1740 = 1426 (TH1177) × C2 (657 × PA)	100	57	36	7
HES 1940....	T1740 = 1426 (TH1177) × C2 (657 × PA)	95	53	40	7
HES 1944....	T1745 = 1435 (TH1168) × C2 (657 × PA)	95	44	50	6
HES 1946....	1537 = TH979 × 936 (Gardner- Bounty)	26	54	27	19
HES 1954....	T1728 = T1369 × T1080	100	46	46	8
HES 1956....	T1740 = 1426 (TH1177) × C2 (657 × PA)	99	52	39	8
HES 1958....	T1745 = 1435 (TH1168) × C2 (657 × PA)	71	48	44	8
HES 1960....	T1863 = 1435 (TH1168) × C2 (657 × PA)	80	54	36	10
HES 1978....	1594 = 1435 (TH1168)	20	100	0	0
HES 2038....	T1863 = 1435 (TH1168) × C2 (657 × PA)	45	29	53	18
Pearl Harbor.		49	0	0	100
Bounty......		63	0	0	100
Pritchard.....		37	0	0	100

*As used in these tests: 1 = no symptoms of injury or, at most, a slight flecking; 2 = well defined lesions present but not sufficient to cause defoliation; 3 = defoliation or killing of plant.

remaining 17 were segregating for resistance. Bounty, Pritchard, and Pearl Harbor, included for breeding purposes and for checks in the inoculation test, were homozygous susceptible.

When the resistant seedlings derived from this test were planted in the field in late summer of 1945, most of the 23 line selections produced

fruits of over 2½ inches and in some, the diameter of the fruits of the first clusters approached 4 inches. Especially promising from the standpoint of size of fruit, high yielding ability and earliness were HES numbers 1887, 1930, 1939, and 1940.

HES 1887 is a derivative of 42–8 Targinnie Red x Bounty double crossed with 657 x Bounty. This, carried to the third generation through selections HES 1417 and 1624 and crossed later with C2 (a Pan American–Pearl Harbor hybrid) was selected as having outstanding commercial possibilities. HES 1887, while heterozygous resistant, was approximately equal to Bounty in fruit size and vigor. Its yielding ability was somewhat lower than that of Bounty.

HES 1939 and HES 1940 are sister selections and have in their parentage a cross made by R. Urata of the Hawaiian Sugar Planters' Association Experiment Station under the designation of TH979. Coming, more specifically, from a complex hybrid of Michigan State Forcing–L. peruvianum x Home Garden crossed with German Sugar x L. pimpinellifolium, they derive their resistance from a source independent of that of HES 1887. There were in the progeny of HES 1939 57 resistant plants and 43 susceptible ones. The ratio in HES 1940 was about the same, 50:45. Both are determinate vine types, more vigorous but smaller-fruited than Bounty. The first is homozygous green-fruited, the latter is white-fruited in the stage just preceding maturity.

In HES 1930, resistance stems from yet a different source. In 1943, 42–19, the resistant parent, was crossed with the F_3 of a BC–10–Bounty hybrid under the code number T813. After two generations of individual plant selection from this line, HES 1432 was isolated and planted. One determinate plant was unusual in respect to fruiting ability (1,364 one-inch fruits) and was crossed with C_2. As an F_2 segregate from the latter cross, HES 1930 when tested for gray leaf spot resistance yielded 25 resistant plants in contrast to 12 susceptibles. While the fruit size of 1930 is but slightly more than 2 inches in diameter, the vine vigor and setting ability exceeds that of Bounty.

While an examination of the data in Table I reveals that many of the selections are still heterozygous for resistance, evidence compiled during the course of the breeding program indicates that with segregating populations, the ratio of resistance to susceptibility may through proper selection be improved from one generation to the next. Thus (Table II), using the same fungus isolate and the same method of inoculation

TABLE II—DISEASE REACTION OF EIGHT TOMATO HYBRIDS IN THREE SUCCESSIVE GENERATIONS

Selection	Present Generation*	1st Generation Back*	2nd Generation Back*
HES 1881	40 to 1	22 to 1	19 to 6
HES 1884	41 to 0	24 to 0	17 to 9
HES 1885	40 to 0	18 to 4	22 to 12
HES 1003	36 to 0	21 to 3	15 to 8
HES 1914	40 to 0	19 to 4	14 to 14
HES 1919	27 to 12	10 to 14	12 to 24
HES 1928	56 to 0	13 to 11	18 to 20
HES 1931	56 to 0	9 to 18	10 to 36
Bounty	0 to 50	0 to 48	0 to 50

*Figures listed in a resistant to susceptible ratio.

and field culture in each generation, the resistance of HES 1931 was increased from a 10:36 ratio in the second generation back to a 56:0 ratio in the present. Likewise, a homozygous resistant line, HES 1928, was obtained in two generations from one segregating 18 resistant plants to 20 susceptibles. The same situation existed in other hybrids also, although it was not necessarily true in every case.

Discussion

The technique of inoculation employed thus far in the breeding operation, although successful in the respect that it has satisfactorily permitted the selection of large-fruited resistant lines, possesses a number of weaknesses which limit its use for determining fine differences in resistance within segregating lines and which, consequently, render the determination of the mode of inheritance of *Stemphylium* resistance difficult.

From experience in testing approximately 15,000 tomato seedlings at the Hawaii Station, variation in plant reaction has been observed to result from irregularities in the inoculum load retained by the plant, through size of inoculum particle applied to the plant, and through placement of inoculum on plant parts. The lack of complete control exercised in the inoculation process is in part responsible for such variations but the importance of such modifying factors as differences in hairiness of leaves and area of leaf surface exposed is also evident.

The possibility of using other methods of inoculation has been considered. The technique employed by Wellman (5) for comparing virulence of isolates of *Alternaria solani* on tomato leaflets has been investigated and found to be not altogether satisfactory under the conditions of these studies. Likewise, various other methods of placing given quantities of mycelial fragments on attached and excised tomato leaves have been discouraging.

In the past, none of the 50 or more collections of the Stemphylium fungus maintained in stock at this Station has produced more than a sprinkling of conidia under ordinary laboratory conditions and the use of spore suspensions, other than those prepared from spores produced by growing plants, in solving the problems of variability was ruled out. Recent attempts, however, to induce heavy sporulation *in vitro* by artificial means have offered encouragement and satisfactory infection has been obtained when these spores have been used in inoculation experiments. Further, spore inoculum containing spores from field grown plants has been successfully used in other phases of the tomato improvement program (2). An obvious advantage of using spores produced *in vitro* is that tests can be conducted without interference from other organisms. The technique has not been standardized to the extent of warranting further discussion, but further effort to modify and refine it is underway.

Summary

Stemphylium solani is a serious foliar parasite of tomatoes in Hawaii. Extensive field and greenhouse inoculation tests have shown that three small-fruited introductions from the United States Department

of Agriculture and five medium-sized introductions from the Experiment Station of the Hawaiian Sugar Planters' Association were resistant to local collections of the pathogen.

Resistant lines were hybridized with commercial varieties and succeeding generations were examined for resistance to the disease and for desirable horticultural characters. In resistance tests, the plants were grown in the greenhouse, artificially inoculated in the seedling stage, incubated under muslin frames, and classified according to the severity of disease development.

At the present time 23 selections are considered promising for combining resistance with large fruit size and heavy yielding ability. Of these, four lines (HES numbers 1887, 1930, 1939, and 1940) are outstanding.

Evidence accumulated so far indicates that with continued hybridization and selection, a large-fruited, high yielding, resistant line can be isolated without undue difficulty.

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Effect of Curing and Time of Topping on Weight Loss and Chemical Composition of Onion Bulbs[1]

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Introduction

There is little information available regarding the effect of curing upon any immediate changes in onion bulbs. Earlier work has dealt largely with the effect of curing on the keeping quality, especially from the disease standpoint. The study herein reported was undertaken to determine how curing and the time of topping affect the weight loss and the chemical composition of the bulbs. Special emphasis was placed on the movement of materials between the tops and the bulbs during the curing process. Such information would be of practical value in determining the best stage to top onions after pulling.

Methods

In three experiments, comparisons were made of weight loss and chemical composition between topped and untopped onions cured under similar conditions for 3-, 6-, and 9-day periods. Immediately after an excess of plants of approximately equal stages of maturity had been pulled, lots were carefully selected so that each contained plants that were similar in size and shape for both bulbs and tops. The work was done by selecting the same number of similar plants as the number of lots for any particular experiment and then placing one plant in each lot. This procedure was followed until the desired number of plants per lot was attained. Duplicate determinations for dry matter were made on all lots. Fresh-weight samples of 100 grams each were dried in a forced-draft oven at 60 degrees C for 48 to 72 hours, at which time they had reached constant weight. For the sugar and alcohol-soluble determinations a single sample from each lot was preserved. Sugar determinations were then made in duplicate from each preserved sample. Reducing sugars were determined by the Quisumbing-Thomas method. Sucrose was inverted, malt imvertase being used at 30 degrees for 18 hours, after which the samples were treated as for reducing sugars. Fructose was determined by the method of Jackson and Mathews (1). Alcohol-soluble materials were those soluble in boiling 80 per cent alcohol. In the calculation of all statistical data, the Standard Error of a Difference Method was used. Odds were obtained from Livermore's (2) table for D/S.E. values.

Experiment 1 was conducted with the Southport White Globe variety in 1944. There were five treatments of five lots or replicates per treatment. Each lot contained 31 plants. The average bulb weight of the lots topped at harvest was 2,416 grams. The tops were relatively small, since the plants were taken from a late seed-planted field. The treatments used were as follows: 1. Topped at harvest; 2. Topped after curing 3 days; 3. Topped after curing 6 days; 4. Topped after

[1]This work was supported in part by a grant from the Basic Vegetable Products Company of Vacaville, California.

curing 9 days; and 5. Topped at harvest. Top and bulb samples from treatments 1 to 4 inclusive were preserved for chemical analysis immediately after topping. Those from treatment 5 were weighed after 3, 6, and 9 days and were then preserved for analysis.

These onions were pulled about 8 a. m. on August 15 and, while curing, were kept out of doors in flats covered with a double thickness of burlap to prevent sun scald. Daily maximum and minimum temperatures were about 87 and 55 degrees F, respectively. Excised tops were kept in the same flat as the bulbs in order to be as comparable as possible with intact plants. Since the tops of the plants varied somewhat in size, the bulb weights of the 15 untopped samples (treatments 2, 3, and 4) were calculated as if they were the same as the 10 lots (treatments 1 and 5) that were topped and weighed at harvest.

Experiments 2 and 3 were conducted in 1945. Two additional treatments were included to give better information regarding the changes that occurred in topped and untopped bulbs after 3 and 6 days of curing. Calculations for bulb weights of untopped plants were made on the basis of bulb-plant ratios from the 20 lots of comparable plants that were topped and weighed at harvest. This method was compared with the water-displacement method; but, since the variations were less when the bulb-top weight relationships were used, the latter method was decided upon.

In experiment 2 the mean bulb weights of the lots topped at harvest were 3,988 grams, and the mean standard error was ±36.12 grams. For the calculated lots comparable figures were 3,953 grams for the bulbs, while the standard errors averaged ±51.02 grams. In experiment 3 the mean bulb weight per lot of those topped at harvest was 3,397 grams, and the standard errors averaged ±27.82 grams. The calculated lots averaged 3,406 grams per lot, with average standard errors of ±31.48 grams.

In experiments 2 and 3 there were seven treatments of five lots per treatment. There were 29 plants per lot in experiment 2, and 31 in experiment 3. The treatments compared were as follows:

Treatment No.	Days of Curing	Time of Topping
1	0	At harvest
2	3	At harvest
3	3	After 3 days
4	6	At harvest
5	6	After 6 days
6	9	At harvest
7	9	After 9 days

Plants from treatment 1 were topped and sampled for analysis at harvest, whereas treatments 2, 4, and 6 were topped at harvest and then cured 3, 6, and 9 days respectively before being preserved for analysis. These were compared with treatments 3, 5, and 7, which were not topped until after being cured for equal periods. Since the plants were cured in open flats in a well-ventilated room with all windows open, the air moved freely over them. Excised tops were kept in the same flats as the bulbs. Experiment 2 involved Southport White Globe plants with large tops that were not over 2 per cent broken over at time of harvest on June 6. The bulbs were large for

the variety. Drying was most rapid between the third and ninth days of curing.

The San Joaquin variety was used for experiment 3. The plants were pulled on June 26. The tops were medium sized, very uniform, and slightly brown at the leaf tips. About 25 per cent of the tops had already broken over, and another 25 per cent broke over at the time of pulling. The bulbs were of medium size. A dry hot wind during the first 5 days' curing caused the tops to dry very rapidly. They were about as dry after 6 as after 9 days.

Results

The results for experiments 2 and 3 are the most complete. Experiment 1 lacked certain treatments necessary for full comparisons. In all three experiments, the bulbs that remained attached to their tops during the curing period, showed an increase in percentage dry matter in comparison with excised bulbs. (See Tables I, II, and III.) In

TABLE I—Effect of Curing and Time of Topping on Dry Matter and Partial Chemical Composition of Onions. Experiment 1

Treatment	Days Cured	Composition as Per Cent of Fresh Weight						
		Dry Matter	Alcohol Insoluble Solids	Alcohol-Soluble Solids	Total Sugars	Sucrose	Reducing Sugars	Fructose
Bulbs								
No. 1—Initial	0	12.12±0.19*	2.82	9.30	5.41	3.01	2.40	0.76
No. 2—Untopped	3	12.85±0.33	3.30	9.55	5.54	2.92	2.62	0.82
No. 3—Untopped	6	12.11±0.26	3.02	9.09	5.52	2.86	2.66	0.84
No. 4—Untopped	9	12.50±0.18	2.75	9.75	5.35	2.75	2.60	0.82
No. 5—Topped	9	11.38±0.33	2.82	8.56	4.95	2.40	2.55	0.86
Tops								
No. 1—Initial	0	13.45	9.27	4.18	1.40	0.38	1.02	0.40
No. 2—Untopped	3	25.96	11.97	13.99	1.40	0.44	0.96	0.35
No. 3—Untopped	6	52.89	18.04	34.85	1.69	0.53	1.16	0.83
No. 4—Untopped	9	64.02	26.50	37.52	1.52	0.44	1.08	0.89
No. 5—Topped	9	69.78	21.14	48.64	2.51	1.33	1.18	1.03

*Standard error of the mean.

experiments 2 and 3, lots cured with tops attached had a larger percentage of dry matter than that found in the original samples. The increase in dry-matter content of untopped bulbs was associated with measurable increases in total sugars and alcohol-soluble solids. There was very little difference in the alcohol-insoluble fractions, regardless of whether or not the bulbs were cured.

Tops that remained attached to the bulbs during curing were much lower in alcohol-soluble materials and sugars per unit of dry weight than tops that were excised.

The data in Table IV show that bulbs cured with their tops on usually had greater weight loss than excised bulbs. These differences in weight loss were sometimes highly significant. Apparently, therefore, the tops were drawing moisture from the bulbs during curing.

TABLE II—EFFECT OF CURING AND TIME OF TOPPING ON DRY MATTER AND PARTIAL CHEMICAL COMPOSITION OF ONIONS. EXPERIMENT 2

Treatment	Days Cured	Composition as Per Cent of Fresh Weight						
		Dry Matter	Alcohol Insoluble Solids	Alcohol-Soluble Solids	Total Sugars	Sucrose	Reducing Sugars	Fructose
		Bulbs						
No. 1—Initial	0	13.56±0.20*	3.46	10.10	6.29	3.51	2.78	1.07
No. 2—Topped	3	13.66±0.04	3.49	10.17	6.17	2.98	3.19	1.05
No. 3—Untopped	—	14.76±0.09	3.69	11.07	7.09	3.96	3.13	0.94
No. 4—Topped	6	13.66±0.10	3.08	10.58	6.62	3.32	3.30	1.06
No. 5—Untopped	—	15.02±0.11	3.21	11.81	6.69	3.34	3.35	1.09
No. 6—Topped	9	13.81±0.13	2.73	11.08	5.95	2.61	3.34	1.09
No. 7—Untopped	—	15.44±0.09	2.95	12.49	6.69	3.65	3.31	0.93
		Tops						
No. 1—Initial	0	10.56±0.06	5.38	5.18	3.44	0.50	2.94	1.68
No. 2—Topped	3	12.83±0.44	6.68	6.15	3.49	1.02	2.47	1.62
No. 3—Untopped	—	10.88±0.10	6.38	4.50	2.62	0.32	2.33	1.69
No. 4—Topped	6	21.33±1.72	6.06	15.27	3.56	1.36	2.20	1.53
No. 5—Untopped	—	18.24±0.62	6.83	11.41	2.28	0.31	1.97	1.20
No. 6—Topped	9	30.86±0.93	9.38	21.48	4.74	2.01	2.73	2.01
No. 7—Untopped	—	32.54±2.11	13.68	18.86	2.22	0.47	1.75	1.17

*Standard error of the mean.

In addition, tops of the plants remaining attached to the bulbs were more turgid and pliable throughout the curing period — a condition which again suggests that they were drawing moisture from the bulbs.

Without exception, when the tops were left attached, the entire plants lost more weight than when the tops were excised, as is shown by Table V. This fact indicates further that the tops draw moisture from the bulbs and lose it to the atmosphere during curing.

TABLE III—EFFECT OF CURING AND TIME OF TOPPING ON DRY MATTER AND PARTIAL CHEMICAL COMPOSITION OF ONIONS. EXPERIMENT 3

Treatment	Cured	Composition as Per Cent of Fresh Weight						
		Dry Matter	Alcohol-Insoluble Solids	Alcohol-Soluble Solids	Total Sugars	Sucrose	Reducing Sugars	Fructose
		Bulbs						
No. 1—Initial	0	7.73±0.09*	1.76	5.97	4.63	0.61	4.02	1.99
No. 2—Topped	3	7.76±0.09	1.62	6.14	5.16	0.69	4.47	2.25
No. 3—Untopped	—	8.59±0.02	1.71	6.88	5.41	0.85	4.56	2.27
No. 4—Topped	6	7.90±0.05	1.61	6.29	5.19	0.61	4.58	2.09
No. 5—Untopped	—	8.51±0.02	1.61	6.90	5.34	0.69	4.65	2.20
No. 6—Topped	9	7.87±0.05	1.53	6.34	5.10	0.59	4.51	2.17
No. 7—Untopped	—	8.57±0.03	1.57	7.00	5.03	0.68	4.35	2.39
		Tops						
No. 1—Initial	0	9.80±0.09	6.12	3.68	1.18	0.17	1.01	0.47
No. 2—Topped	3	24.09±1.12	7.00	14.09	1.43	0.58	0.85	0.45
No. 3—Untopped	—	20.55±1.08	7.40	13.15	0.91	0.08	0.83	0.20
No. 4—Topped	6	55.47±3.86	18.64	36.83	1.94	1.18	0.76	0.50
No. 5—Untopped	—	73.33±2.10	27.60	45.73	1.07	0.40	0.67	0.13
No. 6—Topped	9	82.98±0.97	28.26	54.72	2.40	1.63	0.77	0.49
No. 7—Untopped	—	82.42±0.48	34.86	52.56	0.95	0.33	0.62	0.13

*Standard error of the mean.

TABLE IV—EFFECT OF CURING AND TIME OF TOPPING ON WEIGHT LOSS BY ONION BULBS

Number of Days of Curing	Weight Loss as Per Cent of Original			
	Topped at Harvest	Untopped	Difference	Odds
Experiment No. 1				
3	4.50±0.06	10.06±1.15	5.56	630,277:1
6	6.79±0.10	10.93±0.54	4.84	Infinite
9	7.83±0.13	8.32±0.71	0.49	2:1
Experiment No. 2				
3	3.03±0.07	4.30±0.77	1.27	8:1
6	5.52±0.07	6.35±0.26	0.83	515:1
9	6.99±0.09	5.94±0.66	-1.05	8:1
Experiment No. 3				
3	3.36±0.38	7.84±0.57	4.48	Infinite
6	6.84±0.81	8.05±0.44	1.21	4:1
9	7.88±0.16	9.13±0.45	1.25	143:1

Topping and curing markedly affected the changes in absolute dry matter of onion bulbs, as is seen from Table VI. In experiments 2 and 3, during the curing period there was an increase in the absolute dry-matter content of bulbs which remained attached to the tops, but a decrease in absolute dry matter of bulbs cured without their tops. The increase by the untopped bulbs could be accounted for by movement downward from the tops. On the other hand, the loss by the topped bulbs can be attributed to respiration. The actual effect of curing with the tops on is the difference between the two, which, in experiments 2 and 3, amounted to over 5 per cent of the original dry matter of the bulbs for the first 3 days of curing. The differences were even greater when curing was continued for 6 or 9 days.

Further proof that cutting off the tops prevented the movement of certain dry matter materials out of them during the curing period is

TABLE V—EFFECT OF CURING AND TIME OF TOPPING ON WEIGHT LOSS BY ONION PLANTS (BULBS PLUS TOPS)

Number of Days of Curing	Weight Loss as Per Cent of Original			
	Topped at Harvest	Untopped	Difference	Odds
Experiment No. 1				
3	13.88±0.34	18.38±0.77	4.50	Infinite
6	20.51±0.39	23.55±0.56	3.04	1,000,000:1
9	22.92±0.42	24.28±0.84	1.36	4:1
Experiment No. 2				
3	8.75±0.25	9.50±0.20	0.75	79:1
6	20.30±0.53	23.73±0.49	3.43	384,000:1
9	26.09±0.27	27.93±0.62	1.84	15:1
Experiment No. 3				
3	15.64±0.35	19.66±0.32	4.02	1,000,000:1
6	23.40±1.14	25.12±0.38	1.72	5:1
9	24.09±0.28	25.93±0.32	1.84	58,000:1

TABLE VI—EFFECT OF CURING AND TIME OF TOPPING ON CHANGES IN THE ABSOLUTE DRY MATTER CONTENT OF ONION BULBS

Number of Days of Curing	Change in Absolute Dry Matter in Bulbs, Based on Original			
	Grams		Percentage	
	Topped at Harvest	Untopped	Topped at Harvest	Untopped
	Experiment No. 1			
9	-36.09	-15.95	-13.45	-5.44
	Experiment No. 2			
3	-12.74	+21.98	-2.31	+4.12
6	-25.95	+20.32	-4.82	+3.73
9	-28.04	+40.15	-5.28	+7.56
	Experiment No. 3			
3	- 6.38	+ 7.93	- 3.02	+2.41
6	- 3.20	+12.23	- 4.78	+1.21
9	- 1.99	+16.64	- 6.21	+0.75

afforded by Table VII. The tops all lost in absolute matter whether they were attached to the bulbs during the curing period or not. Attached tops lost much more than tops that were excised. Since the greatest difference between comparable lots was during the first 3 days of curing, evidently the greatest movement of materials from the tops to the bulbs occurred at this time. Presumably the difference between comparable lots is due to the movement of solid materials from the tops to the bulbs during the curing period. This assumption seems justified because sugars and alcohol-soluble materials were much higher in the dry matter of the tops that were detached throughout curing. Also the gain in grams of absolute dry matter by the bulbs agreed well with the loss from the tops, assuming that respiratory losses for tops attached or excised were of the same magnitude.

TABLE VII—EFFECT OF CURING AND TIME OF TOPPING ON CHANGES IN THE ABSOLUTE DRY MATTER CONTENT OF ONION TOPS

Number of Days of Curing	Loss of Absolute Dry Matter in Tops, Based on Original Content			
	Grams		Percentage	
	Topped at Harvest	Untopped	Topped at Harvest	Untopped
	Experiment No. 2			
3	11.01	35.01	6.36	21.09
6	28.28	74.09	17.81	44.24
9	36.53	87.29	21.78	52.99
	Experiment No. 3			
3	4.01	21.66	4.57	24.77
6	16.55	25.52	19.15	29.29
9	1.01	12.32	12.82	14.22

Discussion

The results presented stress two factors: first, that curing under natural conditions causes a weight loss by onion bulbs, whether or not they are topped; second, that solid materials may actually be moving from the tops to the bulbs during the curing period. Bulbs with tops attached lost considerably more weight the first few days of curing than did excised bulbs. This difference had occurred at a time when the tops remained relatively turgid. Seemingly, therefore, the greatest difference in weight loss between excised and untopped bulbs would occur under conditions of relatively slow moisture loss; the least difference, during periods when the tops would remain alive for only a comparatively short time. Judging from weight losses alone, it would be to the growers' advantage to dispose of onion bulbs as soon as possible after pulling, and not to cure the onions.

Bulbs with tops intact were much higher in percentage dry matter after curing than bulbs with the tops cut off. The differences might be due to (a) greater loss of water from intact bulbs due to withdrawal by the tops or (b) movement of solid materials from the tops to the bulbs. Judging from the data presented, both factors operate; but apparently the second factor is the more important, since occasionally there were only slight differences in weight loss between the topped and untopped lots. The gain in dry matter by bulbs that remained intact throughout curing was of the same magnitude as the loss from the tops. The conditions under which there would be the maximum translocation from the tops to the bulbs are not known. Apparently, however, this would be likely to occur under conditions of cool temperatures when respiratory losses are small and under conditions when the tops would remain turgid long enough to permit the movement of materials to the bulbs.

From a practical standpoint, dehydrators of onions would gain appreciably by buying bulbs that have been cured with the tops attached, since these bulbs are so much higher in percentage dry matter; but the grower would be in a more favorable position if he could sell the weight that is present right after topping, with a minimum of curing.

Summary

Topped and non-topped onion bulbs were cured under the same conditions for 3, 6, and 9 days. Comparisons were made of weight loss and chemical composition during the curing period.

Excised bulbs lost about 3 to 5 per cent of their original weight during the first 3 days of curing, and a high of about 8 per cent after 9 days of curing. Bulbs with tops attached lost considerably more weight during the first few days of curing than did excised bulbs. Intact plants lost more weight than the total of bulbs plus tops of plants that had been excised.

A more turgid conditions of the tops of untopped plants during the curing period indicated that they were removing water from the bulbs. Bulbs cured with tops attached were significantly higher in percentage dry matter after 3, 6, or 9 days than excised bulbs. Bulbs cured with tops intact were higher in absolute dry matter after curing than

excised bulbs. Excised tops were higher in percentage dry matter, alcohol-soluble solids, total sugars, and sucrose during curing than were tops that remained attached to the bulb. All data indicate the movement of a substance or substances from the tops to the bulbs during the curing period.

Literature Cited

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Response of Chinese Cabbage to Temperature and Photoperiod

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Difficulties encountered in producing Chinese cabbage *(Brassica pekinensis)* commercially are stressed in various texts and seed catalogs. When planted at Davis, this short-lived annual normally produces flowers within 4 months or less. If grown at certain seasons of the year it may produce seedstalks very quickly, sometimes without even forming a head. When grown during the hot weather it is bitter and of poor quality. If this vegetable could be grown satisfactorily, it might have consumption comparable with that of lettuce. Under proper conditions it yields several times as much per acre as lettuce; furthermore, it is better adapted to holding in storage. The investigation here reported was initiated because of the hazards in producing Chinese cabbage under California conditions.

Review of Literature

There is only meager information regarding the effect of the various environmental factors on growth and flower formation in Chinese cabbage. Bremer (1) in Germany grew plants under natural and 11½ hour day lengths during July and August. He found that flowering occurred most rapidly under the natural day of about 18 hours duration. The strains he studied developed seedstalks in the following order: Pe Tsai, Wong Bok, and Chihli. Kraus, (3) working in Wyoming, states that temperature and soil-moisture supply are probably important factors in premature seedstalk formation. With the varieties Wong Bok and Chihli, the highest percentage of plants heading were obtained from those that had been planted from June 1 to July 1 inclusive. These plants were grown under long days, which ranged from about 13 to 15½ hours.

According to Thompson, (4) Chinese cabbage is grown in the South as a winter crop and elsewhere in this country as a fall crop; if it is planted for an early summer crop, the plants go to seed without forming a head. Various seed catalogs have recommended fall plantings for the northern climates, fall and winter plantings for the South. Practically all the catalogs have attributed the seedstalk formation of this vegetable in the summer to hot weather.

Plan of Investigation

There were three main phases of study. The first was the planting of different varieties and strains at Davis each month throughout the year and observing their behavior, especially rate of growth, head formation, and flower formation. Observations were also made on this vegetable as produced at other locations in California. A second study involved keeping the plants in greenhouses where length of day and temperature were varied. In the third phase plants were exposed to low temperatures for varying lengths of time to determine the effect on flower-stalk appearance.

The greenhouse and temperature-induction experiments were all conducted at Davis. Heating of the greenhouses was thermostatically controlled. Cooling, when required, was provided by proper manipulation of the ventilators. Temperature variations during the winter and early spring were small. After March 15, daily temperatures sometimes rose above the maximum desired, but night temperatures varied but little from those wanted. Thermograph records were kept so that any variations from the desired temperature were detected.

When day lengths shorter than the natural were used, cages made of black satin were placed over the plants at 4:30 p. m. and then removed at the desired time the following morning. Day lengths longer than natural were provided by a single 40-watt daylight fluorescent lamp placed over each cage containing about 30 plants. The lamp was approximately 3 feet above the top of the pots and was covered with a reflector.

Experiments and Results

Time of Planting Studies

In the time of planting studies, 11 strains were seeded in the field at Davis on the 15th of every month from July, 1943 until November, 1944. Records were kept of the size and quality of head, the time of flowering, and other behavior. These strains involved five of the Wong Bok variety, four of Chihli, and two of Pe Tsai. The behavior of all strains was similar; but, of those studied, a strain of Pe Tsai furnished by the Ferry Morse Seed Company was the most resistant to flowering. Table I presents the performance of a typical strain of Chihli grown throughout the year. The number of days required for 50 per cent of the plants to bloom was derived by counting at 10-day intervals the number in bloom and then interpolating to the nearest 5-day interval. Data on the average monthly temperature and day length are provided for comparison.

TABLE I—Performance of a Strain of Chihli Chinese Cabbage Planted at Davis on the 15th of Every Month from July, 1943 to July, 1944

Date of Planting	Average Monthly Temperature	Approximate Day Length (Hours)	Relative Size of Plant Before Open Flowers	Approximate Days When 50 Per Cent of Plants Showed Open Flowers	Notes on Performance
Jul	75.8	14.7	Large	100	Large, excellent heads
Aug	72.0	13.8	Large	125	Large, excellent heads
Sep	72.3	12.3	Medium	120	Some heads
Oct	61.7	11.2	Small	125	Early seedstalk, heads small
Nov	53.8	10.0	Small	110	Seedstalk when plants less than 6 inches high. Did not form heads.
Dec	47.6	9.3	Small	100	
Jan	46.0	9.7	Small	75	
Feb	48.0	10.8	Small	65	
Mar	53.6	11.9	Small	75	
Apr	54.8	13.1	Medium	80	Formed heads, but of poor quality—soft, strong, and bitter
May	64.6	14.5	Large	85	
Jun	68.0	15.0	Large	105	
Jul	72.6	14.7	—	—	
Aug	73.4	13.8	—	—	
Sep	73.4	12.3	—	—	

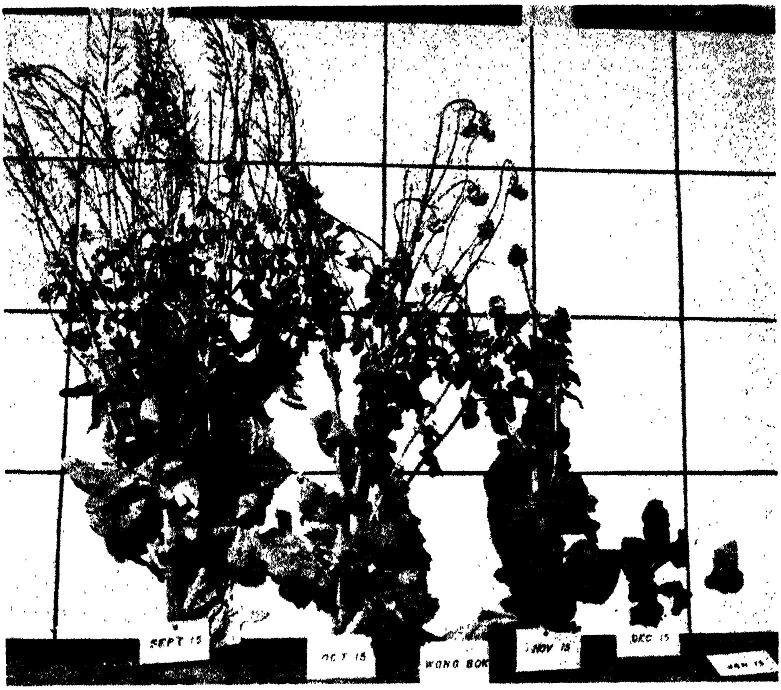

FIG. 1. Effect of planting date on size of plant and seedstem development. Variety Wong Bok; photographed March 15, 1944. Note the large size of the September and October plants when flowering. Plantings made in December and January show flower buds.

Heading of plants was obtained from plantings made from April through September. Good-quality Chinese cabbage was produced, however, only from late-summer and early-fall plantings (July to September). Plantings made in late fall, winter, and early spring produced flowers without forming any heads. Plantings made in December and January showed flower buds when as few as two true leaves were present. Some of these plants showed open flowers when the flower stalk was only about 6 inches high, as compared with about 4 feet for August plantings. Late-spring plantings (April through June), maturing in the summer, formed heads that were soft and of poor quality, strong and bitter in flavor. Once headed, they remained in this condition for a comparatively long time before developing seedstalks. The figures giving the length of time from planting until flowering are slightly misleading; for example, plantings made in midwinter showed visible flower buds within 2 weeks after the plants were up and when they had only four to six true leaves, yet blooming did not occur until several months later. The cold weather during the winter growing period greatly delayed growth between the time of flower-bud formation and actual blooming.

Experiments on the Effect of Day Length and Temperature

In three separate experiments, the temperature and the day length were varied. Since treatments were not always identical, the results of each experiment are discussed separately. In the first experiment one strain of each of the three varieties was grown. There were two sets of temperature conditions and three day lengths. One greenhouse was maintained at 70 degrees F during the day and 60 degrees F at night, while the other was run at 60 degrees F in the daytime and 50 degrees F at night. These are referred to as the 70 to 60 degree house and the 60 to 50 degree house, respectively. The day lengths were 8 hours natural, and about 16 hours. For the 8-hour day the plants were shaded from 4:30 p. m. until 8:30 a. m. In the long-day treatments, artificial light was provided from 4:30 to 10:30 p. m. Natural day length during the period varied from about 10 hours in January to 13 hours in April. The seeds were sown in 6-inch clay pots on December 14, 1943. By December 25, plants in the 70 to 60 degree house were just breaking through the soil. The day-length treatments were begun December 25. Originally, each treatment in the 70 to 60 degree house contained 10 plants of each variety; and the 60 to 50 degree house, 8 plants. The results appear in Tables II and III.

At both temperatures and with all varieties, flower buds and also flowering occurred earliest at long day, next at natural day, and latest under short day. Differences due to variety were not great, although Wong Bok appeared to flower the most rapidly and Pe Tsai the least.

TABLE II—Effect of Temperature and Day Length on Flower Bud Formation in Three Varieties of Chinese Cabbage
Winter 1943–1944

Treatment	Percentage of Plants Showing Visible Flower Buds on the Following Dates								
	Feb 10	Feb 20	Feb 30	Mar 10	Mar 20	Mar 30	Apr 10	Apr 20	Apr 30
				70–60 Degree House					
Wong Bok									
16 hours	0	55	67	78	100	—	—	—	—
Natural	0	0	0	0	0	11	67	100	—
8 hours	0	0	0	0	0	50	100	—	—
Chihli									
16 hours	0	0	10	10	60	100	—	—	—
Natural	0	0	0	0	0	13	100	—	—
8 hours	0	0	0	0	0	0	0	50	100
Pe Tsai									
16 hours	0	0	0	0	44	100	—	—	—
Natural	0	0	0	0	33	67	100	—	—
8 hours	0	0	0	0	0	33	100	—	—
				60–50 Degree House					
Wong Bok									
16 hours	50	63	75	87	100	—	—	—	—
Natural	0	0	0	60	100	—	—	—	—
8 hours	0	0	0	0	25	75	100	—	—
Chihli									
16 hours	12	12	25	37	87	100	—	—	—
Natural	0	0	0	20	80	100	—	—	—
8 hours	0	0	0	0	11	22	77	100	—
Pe Tsai									
16 hours	0	0	25	63	75	100	—	—	—
Natural	0	0	0	11	44	100	—	—	—
8 hours	0	0	0	0	0	0	50	100	—

TABLE III—EFFECT OF TEMPERATURE AND DAY LENGTH ON FLOWERING IN THREE VARIETIES OF CHINESE CABBAGE, WINTER 1943–1944

Treatment	Percentage of Plants with Open Flowers on the Following Dates										
	Feb 10	Feb 20	Mar 1	Mar 10	Mar 20	Mar 30	Apr 10	Apr 20	Apr 30	May 10	May 20
70–60 Degree House											
Wong Bok											
16 hours....	0	0	33	33	78	100	—	—	—	—	—
Natural....	0	0	0	0	0	0	11	56	100	—	—
8 hours.....	0	0	0	0	0	0	29	29	57	71	100
Chihli											
16 hours....	0	0	0	0	20	20	100	—	—	—	—
Natural....	0	0	0	0	0	0	29	86	100	—	—
8 hours.....	0	0	0	0	0	0	0	25	50	100	—
Pe Tsai											
16 hours....	0	0	0	0	0	44	100	—	—	—	—
Natural....	0	0	0	0	0	33	50	50	100	—	—
8 hours.....	0	0	0	0	0	0	0	11	44	78	100
60–50 Degree House											
Wong Bok											
16 hours....	12	25	25	37	87	100	—	—	—	—	—
Natural....	0	0	0	0	20	38	100	—	—	—	—
8 hours.....	0	0	0	0	0	25	75	88	100	—	—
Chihli											
16 hours....	0	0	0	12	37	37	100	—	—	—	—
Natural....	0	0	0	0	10	60	100	—	—	—	—
8 hours.....	0	0	0	0	0	4	44	20	100	—	—
Pe Tsai											
16 hours....	0	0	0	0	37	75	100	—	—	—	—
Natural....	0	0	0	0	0	22	77	100	—	—	—
8 hours.....	0	0	0	0	0	0	0	25	100	—	—

For a given day length, flowering occurred more rapidly in the 60 to 50 degree house than in the 70 to 60 degree. The earliest flowering was with the Wong Bok variety grown in the 60 to 50 degree house under the 16-hour day. Excellent Chinese cabbage was produced in the 70 to 60 degree house, the heads being large, solid, and of pleasant flavor.

A similar experiment was conducted in the winter of 1944–45 except that only two varieties, Wong Bok and Pe Tsai, were used. Two additional temperature treatments were tried. One series of plants was grown out of doors in a lath-house, but with day length controlled as described previously for the greenhouses; other plants were grown in a very hot greenhouse, where the temperature was not accurately controlled but varied from a day-time high of 90 to 110 degrees F to about 80 degrees F at night. In this, the 90 to 80 degree house, the plants were grown only under natural day length.

Seeds for all treatments were planted in pots in the 70 to 60 degree house on November 17, 1944, and transferred to the other houses on December 1, the date when the length-of-day and temperature treatments were begun. When transferred, the plants had one true leaf. In each treatment there were 12 plants of each variety. Table IV shows the results.

The observations on plants in the two greenhouses agree with those obtained in the 1943–44 experiments, although the differences are less pronounced. At comparable day lengths, flowering occurred earlier in the 60 to 50 degree house than in the 70 to 60 degree. Plants grown

TABLE IV—EFFECT OF TEMPERATURE AND DAY LENGTH ON FLOWERING OF TWO VARIETIES OF CHINESE CABBAGE

Treatment	Percentage of Plants With Open Flowers on the Following Dates						
	Mar 1	Mar 10	Mar 20	Mar 30	Apr 10	Apr 20	Jul 10
			70–60 Degree House				
Wong Bok							
16 hours	0	0	64	100	—	—	—
Natural	0	0	15	44	100	—	—
8 hours	0	0	18	45	100	—	—
Pe Tsai							
16 hours	0	9	18	55	100	—	—
Natural	0	0	36	55	100	—	—
8 hours	0	0	16	50	100	—	—
			60–50 Degree House				
Wong Bok							
16 hours	10	40	100	—	—	—	—
Natural	0	92	100	—	—	—	—
8 hours	0	30	90	100	—	—	—
Pe Tsai							
16 hours	0	10	80	100	—	—	—
Natural	0	30	60	100	—	—	—
8 hours	0	0	40	80	90	100	—
		Outside					
Wong Bok							
16 hours	25	95	100	—	—	—	—
Natural	0	0	75	100	—	—	—
8 hours	0	0	9	73	91	100	—
Pa Tsai							
16 hours	0	66	100	—	—	—	—
Natural	0	0	27	100	—	—	—
8 hours	0	0	0	0	70	100	—
		90–80 Degree House					
Natural day							
Wong Bok	0	0	0	0	0	0	10*
Pe Tsai	0	0	0	0	0	0	10*

*These were the only plants in this treatment to flower. All other plants remained vegetative until after August 1, 1945, when they were lost by rotting.

under a 16-hour day flowered earlier than those under an 8-hour day. In time of actual flowering, there was little difference between the plants grown outside and those in the 60 to 50 degree house. Those outside, however, showed flower buds at least 1 month earlier than those in the greenhouse and therefore took longer from the time of flower induction to blooming. The first plants to produce visible flower buds were those grown outside under the 16-hour day. In the very hot greenhouse (90–80 degrees) only one plant of each variety had flowered by August 1. After this date the others were lost by rotting before they had flowered. The high temperature had practically inhibited flowering.

The third experiment involved growing the plants in greenhouses during the summer of 1944. The seed was planted May 17, and the length-of-day treatments begun on May 31, when the plants were 1 to 2 inches tall and had the second true leaf. There were 15 plants of each variety in each day-length treatment. During the growth period it was not possible to control the maximum day temperature, which usually reached a high of about 110 degrees F. Night temperatures were not allowed to fall below 70 degrees F. The results (Table V) show that under a long day Pe Tsai flowered more slowly than the other varieties.

FIG. 2. Effect of length of day on flowering: (A) 8-hour day, (B) natural day, (C) 16-hour day. All plants grown outside beginning December 1, 1944. Photographed March 5, 1945.

By early October under the 16-hour day all plants had flowered, while under the short day, flowering had occurred in only one plant of the Wong Bok variety and in none of the Chihli or the Pe Tsai. After October 10, plants grown in the 8-hour day were lost by rotting; but up to this time they had shown no flower buds and given no indication of flowering. The short days under the condition of very high temperature had inhibited flowering for a period of at least 3 months.

EXPERIMENTS ON THE EFFECT OF LOW TEMPERATURE ON FLOWER INDUCTION

There were three experiments designed to test the effect of short exposures to low temperature on flower induction. The same strain of

TABLE V—EFFECT OF DAY LENGTH ON FLOWERING IN THREE VARIETIES OF CHINESE CABBAGE, SUMMER, 1944

Treatment	Percentage of Plants With Open Flowers on the Following Dates								
	Jul 30	Aug 10	Aug 20	Aug 30	Sep 10	Sep 20	Sep 30	Oct 10	Oct 20
Wong Bok									
16 hours	9	9	36	73	73	73	90	100	—
8 hours	0	0	0	0	7	7	7	Rotted off (no flowers)	
Chihli									
16 hours	31	38	54	77	77	85	100	—	—
8 hours	0	0	0	0	0	0	0	Rotted off (no flowers)	
Pe Tsai									
16 hours	0	0	0	0	22	33	56	78	100
8 hours	0	0	0	0	0	0	0	Rotted off (no flowers)	

Pe Tsai was used in all experiments, with results that will now be presented separately.

In the first experiment, seeds were planted in pots in the 70–60 degree greenhouse; and after the plants were up, they were grown for different lengths of time outside in a lath-house. Seeds for all lots were planted December 12, 1943. There were 15 plants in each lot. Lots A and B were taken outside on January 14, when the plants had two or three true leaves apiece and were about 3 inches tall. Lot A was returned to the greenhouse after 4 weeks, and B after 2 weeks. At the time of return to the greenhouse, plants of lot B had five to six true leaves and were about 3 inches tall, whereas those of A had about eight true leaves and had reached about 4 inches. Plants of lot C were allowed to grow in the greenhouse until January 27, when they had ten leaves and were 6 inches high. They were moved at this stage to the lath-house, kept there until February 26, and then returned to the greenhouse. Outside mean temperatures during the time the plants remained outdoors were 46 degrees F (January, 1944) and 48 degrees F (February). Plants of lot D were grown continuously in the 70–60 degree greenhouse. The results are given in Table VI.

TABLE VI—Effect of Exposure to Low Temperature on Flowering of Chinese Cabbage. 1943–1944.

Treatment	Percentage of Plants with Open Flowers on the Following Dates				
	Mar 20	Mar 30	Apr 10	Apr 20	Apr 30
Lot A	13	100	—	—	—
Lot B	7	43	71	100	—
Lot C	–	13	100	--	—
Lot D	—	33	50	50	100

Key: all plants grown in 70–60 degree house from December 12, 1943, until transfer date.
Lot A. Transferred outside January 14. Returned to 70–60 degree house February 12 (26 days).
Lot B. Transferred outside January 14. Returned to 70–60 degree house January 27 (13 days).
Lot C. Transferred outside January 27. Returned to 70–60 degree house February 26 (30 days).
Lot D. Grown continuously in 70–60 degree house.

Exposure of the young plants to outside temperatures of approximately 46 degrees F for one month greatly hastened flowering. Exposure for as short a time as 2 weeks hastened flowering as compared with plants grown continuously at the higher temperature. Plants given 1 month of cold treatment not only flowered earlier than those grown continuously inside, but were much more uniform in time of flowering. Young plants exposed to the outside cold for 1 month (Lot A) formed no heads whatever, but immediately sent up seedstalks. Plants of the same age placed outside for only 2 weeks formed small heads before seeding. Plants grown continuously in the greenhouse formed large solid heads and then seeded.

The second experiment, a repetition of the first, was conducted the following winter. The plants (15 in each lot) were started in pots in the 70–60 degree house on November 17, 1944. Lots A and B were transferred outside on December 1, at the cotyledon stage. Lot A was transferred to the greenhouse on December 22, and B on January 17. Lot C was set outdoors on December 22, when the plants had six to twelve and were 6 to 8 inches tall; it was returned to the greenhouse on

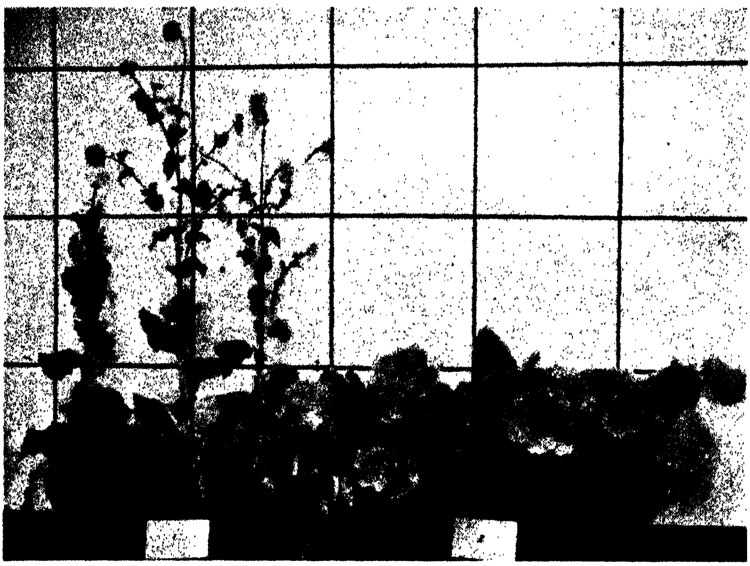

FIG. 3. Effect of exposure to low temperature on flower-stem development. (1) Plants grown outside in lath-house December 1, 1944 to January 17, 1945. (2) Plants grown continuously in 70–60° F greenhouse. Photographed March 5, 1945.

January 17. Lot D was taken out on January 17 and returned to the greenhouse on February 11. The mean outside temperatures during the transfer period were as follows: December, 1944, 46.8 degrees F; January, 1945, 44.0 degrees F; and February, 1945, 50 degrees F.

The results (Table VII) agree with those obtained the previous year. Exposure of very young plants to low temperature for 3 to 6 weeks greatly increased the rapidity and uniformity of flowering.

In the third experiment testing the effect of cold exposure on flower induction, 20 plants of each treatment were grown in the greenhouse during the hot summer months. The seeds were planted in pots May 17, 1944. On June 20 plants to be given the cold treatment were taken

TABLE VII—EFFECT OF EXPOSURE TO LOW TEMPERATURE ON FLOWERING OF CHINESE CABBAGE, 1944–45

Treatment	Percentage of Plants with Open Flowers on the Following Dates					
	Feb 20	Mar 1	Mar 10	Mar 20	Mar 30	Apr 10
Lot A.	14	36	100	—	—	—
Lot B.	0	33	100	—	—	—
Lot C.	0	0	100	—	—	—
Lot D.	0	0	13	73	100	—
Lot E.	0	0	0	36	55	100

Key: All plants grown in 70–60 degree house until transferred.
Lot A. Transferred outside December 1. Returned to 70–60 degree house December 22 (21 days).
Lot B. Transferred outside December 1. Returned to 70–60 degree house January 17 (47 days).
Lot C. Transferred outside December 22. Returned to 70–60 degree house January 17 (26 days).
Lot D. Transferred outside January 17. Returned to 70–60 degree house February 11 (24 days).
Lot E. Grown continuously in 70–60 degree house.

to a 40 degree F cold-storage room, where the day length was maintained at 15 hours, a period comparable with the natural day length for that season of the year. Two 40-watt daylight fluorescent bulbs were the source of light. On July 6 the plants were returned to the greenhouse. There the day temperatures varied from about 90 degrees to 110 degrees F, while the night temperatures were not allowed to fall below 70 degrees F. Plants exposed to the 40 degrees F temperature for about 16 days flowered more than a month earlier than plants grown continuously in the hot greenhouse.

TABLE VIII—EFFECT OF COLD TREATMENT OF FLOWERING OF CHINESE CABBAGE

Treatment	Percentage of Plants with Open Flowers on the Following Dates						
	Aug 20	Aug 30	Sep 10	Sep 20	Sep 30	Oct 10	Oct 20
Cold exposure*	45	90	100	—	—	—	—
Continuous high temperature	—	—	22	33	56	78	100

*Transferred to 40 degrees F room June 20, 1944. Returned to greenhouse July 6, 1944.

DISCUSSION

The results reported in this paper show that both temperature and length of day have an important effect upon seedstalk formation by Chinese cabbage. This crop seems to remain vegetative for the longest time when grown under a short day of relatively high temperature. On the other hand, heads that form under high temperatures (above 75 degrees F) are soft and have a bitter taste. High-quality Chinese cabbage can be produced only under moderate to cool temperatures (for example 60 to 70 degrees F). Below 60 degrees F, seedstalks may form before good heads can be produced. The results obtained here agree very well with observations of Frazier (2) who recommends that in Hawaii this crop be grown at or near a mean temperature of 60 to 70 degrees F. At that latitude the days are fairly uniform in length and probably short enough so that early seedstalks are not induced.

According to most seed catalogs, seedstalk formation by Chinese cabbage in the early summer can be attributed to high temperatures. In view of the results obtained here, however, it may better be attributed to the long days at that time of year. Early-spring plantings are not profitable in the northern states because here the plantings are exposed to the low temperature of early spring and to long days, both of which hasten flowering. Evidently the crop is adapted for late-summer or early-fall plantings in the north, where the days are short and the temperatures are low enough to allow good quality, but not so low as to induce early flowering. For the same reason, Chinese cabbage makes a successful winter crop in the southern states.

SUMMARY

The data here reported include results of studies on (a) the effect of planting date and of variety on the performance of Chinese cabbage at Davis; (b) the effect of temperature and day length on seedstalk

formation; and (c) the effect of intermittent exposures to low temperature on flower-bud induction and subsequent flowering.

In the trials at Davis, good-quality Chinese cabbage was obtained only from late-summer and early-fall plantings (July to September, inclusive). Late fall, winter, and early spring plantings produced flowers without forming any heads. Late spring and summer plantings made heads, but of poor quality.

Given equal temperatures within a range conducive to flowering, the plants flowered more rapidly under a 16-hour than an 8-hour day.

Flowering was practically inhibited under natural or short days at temperatures averaging 80 to 90 degrees or higher.

Flower induction was hastened as the temperature was lowered from about 70 to below 50 degrees F at equal day length.

Exposure of plants to outside temperatures averaging about 47 degrees F for as short a time as 2 weeks greatly hastened flowering when the plants were subsequently placed at higher temperatures.

Exposure of plants for 16 days in a constant-temperature room at 40 degrees F markedly increased the rate and uniformity of flowering.

Seemingly the most rapid flowering could be obtained by subjecting the plants, as soon as true leaves form, to temperatures of about 40 degrees F under long day for about 2 weeks or longer, to induce flowering; and then to grow them at a high temperature with long day until flowering.

Plants would probably remain vegetative for the longest time if grown at a very high temperature (above 70 degrees F average) and with a short day.

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Natural Crossing in Sweet Spanish Onions as Related to Distance and Direction

By W. C. Sparks and A. M. Binkley, *Colorado Agricultural Experiment Station, Fort Collins, Colo.*[1]

For the production of onion seed for certification in Colorado seed fields of different varieties or strains must be separated by at least ¼ mile. At the present time there is little information on the amount of natural crossing that will take place when two varieties of onions are grown at various distances from one another.

Since onion flowers are mainly insect-pollinated, the amount of crossing that would occur between fields would seem to depend upon the insect population, direction of the prevailing winds, kind and height of barriers between seed fields, and weather conditions at pollinating time.

During the summer of 1943 an opportunity to make an exploratory study on the amount of natural crossing between White Sweet Spanish and Yellow Sweet Spanish onions presented itself in a commercial planting in Delta County, Colorado. The two varieties were on flat land and separated only by a small irrigation ditch so that the two fields were 30 feet apart. The ditch banks were about 3 feet high and at pollinating time the weeds on the ditch banks were about 3 feet tall, so that the tops of the weeds were about 3 feet above the level of the onion seed heads. The prevailing winds were from the southeast, blowing across the White Sweet Spanish field to the Yellow Sweet Spanish field (Fig. 1).

To determine the per cent crossing between the two varieties and the distance to which the crossing extended across the field, samples of seed were taken at three distances from the ditch. At each distance, three samples were taken, each sample consisting of one large seed head containing from 200 to 300 seeds. The first series of these seed samples of the Yellow Sweet Spanish variety was taken 35 feet from and parallel to the first row of White Sweet Spanish. The first sample of this first series was taken 100 feet from the northeast edge of the field; the second, 250 feet south of the first; and the third, 100 feet from the southwest edge of the field. The second series of samples was taken parallel to the first series, 180 feet from the field of White Sweet Spanish and at the same distance from the edge of the field as the first series. The third series of samples was collected 780 feet from the field of White Sweet Spanish, or about 50 feet from the west edge of the field. Three series of samples were taken in a similar manner.

Rieman (2), and Clarke, Jones, and Little (1) have shown that there are two types of white bulb color; one is a recessive white which is due to the recessive condition of the I and C genes, and the other is a dominant white which is due to the dominant I gene (1). Since it was not known in which class these strains of the Sweet Spanish variety of onion belonged, the field of White Sweet Spanish was sampled

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in a manner similar to that followed in the field of Yellow Sweet Spanish.

The samples of seed from each field were planted and the resulting plants grown to maturity. Counts were taken of the number of white and yellow bulbs in each sample of both the White and Yellow Sweet Spanish, and from these counts the per cent crossing was determined. Fig. 1 shows the position of each sample and the per cent crossing that occurred at each position.

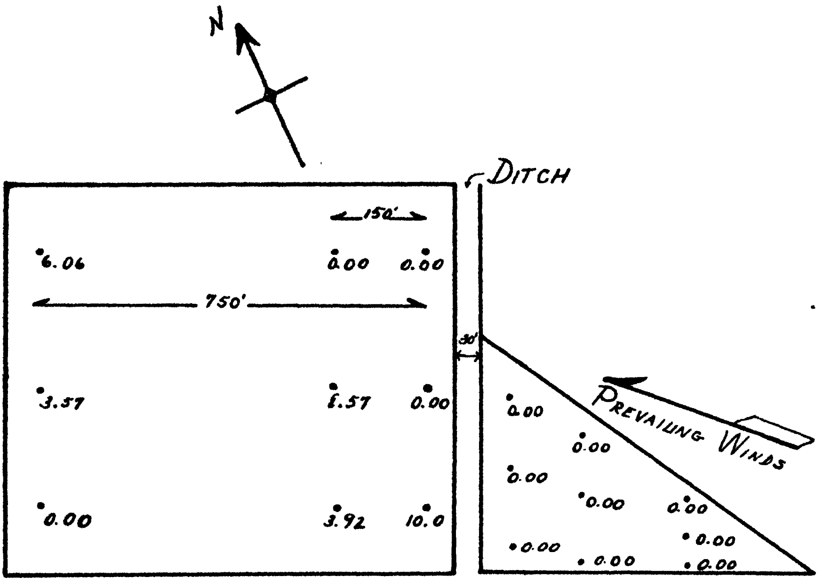

Fig. 1. Diagram of field and position of samples with per cent crossings at each position.

No yellow bulbs appeared in the bulbs grown from the seed samples taken from the field of White Sweet Spanish.

In the bulbs grown from the seed samples taken from the field of Yellow Sweet Spanish, many white bulbs appeared. In one sample from the 35-foot distance 10 per cent of the bulbs were white. This was in the southernmost sample adjacent to the White Sweet Spanish field and in line with the prevailing wind. In the second series of samples, which was taken 180 feet from and parallel to the first row of White Sweet Spanish, white bulbs occurred in two of the samples. In the southernmost sample 3.92 per cent of the bulbs were white, and in the center sample 8.57 per cent were white. Both these samples were in direct line with the prevailing wind and the field of White Sweet Spanish. Two of the three samples in the third series, which was 780 feet from the Whites, contained white bulbs. The center sample contained 3.57 per cent white bulbs and the northernmost sample 6.06 per cent. Both these samples were in direct line with the field of White Sweet Spanish and the prevailing wind.

From these data it can be assumed that the white bulb color of this

strain of White Sweet Spanish is of the dominant I nature, and that all white bulbs that appeared in the samples taken from the field of Yellow Sweet Spanish were due to crossing. It can also be assumed that this strain of White Sweet Spanish is homozygous for the I gene, since no yellow bulbs were encountered in any of the samples taken from the White Sweet Spanish field. If the strain had been heterozygous for I, a few yellow bulbs would have been obtained due to segregation. Although each sample consisted of only one large seed head, the amount of crossing that did occur at 780 feet in the direct line of the prevailing wind, indicates the importance of isolation of seed onion fields. Also, since each seed head contained at least 200 seeds and only a few flowers are receptive at one time, it seems unlikely that the 6 per cent crossing which occurred at 780 feet was the result of only one insect visitation. Of course, it is true that had a larger sample been taken a more accurate figure on the per cent crossing would have been obtained.

It can be seen that crossing occurred most frequently in direct line with the prevailing wind with 6 per cent occurring at a distance of 780 feet. Because of the limitations of this field it is still not known how much crossing would occur at greater distances.

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Germination of Endive Seed *(Cichorium endivia)* at High Temperature Stimulated by Thiourea and by Water Treatments

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Thompson and Kosar (1) and Thompson and Horn (2) have shown that the percentage of germination of lettuce can be increased by treating it with a dilute (0.5 per cent) solution of thiourea. Treating the seed with water alone, although less effective than the thiourea solution, resulted in significant increase in germination of most lots of lettuce seed tested.

More recently, Tukey and Carlson (3) have reported on investigations which show that the germination of peach seed is aided by the thiourea treatment. They found a 0.25 per cent solution to be about optimum for the materials studied, however concentrations ranging from 0.1 to 0.5 per cent were about equally effective when the length of treatment was properly controlled. The higher concentrations are more likely to injure some embryos.

No satisfactory explanation has yet been advanced for the action of thiourea in promoting germination. Further study will no doubt reveal other seeds that respond to thiourea. The evidence to date indicates that not all seeds are favorably affected by this chemical. The writer has not been able to find conditions of treatment that will increase the germination of carrot seed. A large number of tests on the seed of annual larkspur have not been effective.

Seed of certain varieties of endive *(Cichorium endivia)* have been found to respond to the thiourea treatment under conditions similar to those found to be effective on lettuce seed. The present paper is a report of some of the results obtained from the treating of endive seed with thiourea.

Experimental Tests

The tests made on endive seed were carried out by the same technique as reported for lettuce seed (2). In the summer of 1944 several samples of endive seed were obtained from Dr. Oren L. Justice, Office of Marketing Services, Agricultural Research Center, Beltsville, Maryland for preliminary tests.

A few tests using various concentrations of thiourea indicated that the 0.5 per cent solution which had been found optimum for lettuce is also near the optimum for endive seed. A 0.5 per cent solution of thiourea was used throughout the tests on endive seed.

Series 1:—The first tests were made on three different stocks of endive seed. Portions of each stock were treated with a 0.5 per cent solution in Petri dishes in darkness at 18 and 25 degrees C for periods of 4, 8, 16, and 24 hours. The seed on removal from the solution were spread thinly on pieces of absorbent paper and thoroughly dried in diffused light. An equal number of samples of each stock of seed were treated with water at the same temperatures and for the same periods of time. The water-treated seed were dried in the same manner as the

thiourea treated lots. The seed were treated September 19, 1944 and after thoroughly drying were stored for 10 days at room temperature (18 to 25 degrees C). On September 29, 1944, each lot was tested for germination in Petri dishes on moist paper at 30 degrees. The tests were made in quadruplicates of 25 seed each. The results of the germination tests from Series 1 are given in Table I.

TABLE I—SUMMARY OF DATA FROM SERIES 1, SHOWING TOTAL GERMINATION OF QUADRUPLICATE LOTS OF 25 ENDIVE SEED TREATED WITH THIOUREA AND WITH WATER, SEPTEMBER 19, 1944. (GERMINATION TESTS MADE AT 30 TO 31 DEGREES C, BEGINNING OCTOBER 29, 1944; COUNTS MADE AFTER 72 HOURS)

Seed Stock	Number Germinating Out of 100 When Treated as Indicated																
	Thiourea								Water								Untreated (Check)
	18 Degrees C				25 Degrees C				18 Degrees C				25 Degrees C				
	4 Hours	8 Hours	16 Hours	24 Hours	4 Hours	8 Hours	16 Hours	24 Hours	4 Hours	8 Hours	16 Hours	24 Hours	4 Hours	8 Hours	16 Hours	24 Hours	
1	65	79	75	77	69	79	69	65	42	76	65	63	61	56	61	66	40
2	77	79	81	76	77	83	85	75	46	81	79	84	59	73	75	75	16
3	67	72	72	66	68	64	68	60	45	69	68	63	47	63	72	63	26
Total...	209	230	228	219	214	226	222	200	133	226	212	210	167	192	208	204	82
Percentage...	69.7	76.7	76.0	73.0	71.3	75.3	74.0	66.7	44.3	75.3	70.7	70.0	55.7	64.0	69.3	68.0	27.3

Series 2:—In the fall of 1944, additional lots of endive seed were obtained. Eighteen different seed stocks were included. In this series only thiourea was used and all treatments were made at 18 degrees C for 8 hours, since the results from Series 1 indicated these conditions to be the best in the range tested. The seed was treated, November 10, 1944, and after thoroughly drying were stored at room temperature 20 to 25 degrees C. After 1 week in storage all lots of treated seed and an untreated check were tested for germination in quadruplicate at 32 degrees C. The results from Series 2 are presented in Table II.

In both series the germination tests were carried out at a relatively high temperature for the germination of endive seed in order to show the influence of the treatments on germination under unfavorable temperature conditions.

RESULTS

The data presented in Tables I and II indicate that the germination of many lots of endive seed can be greatly increased by treatment with thiourea or water. These data show some striking contrasts between the responses of endive seed to the thiourea and water treatments and the responses obtained from similar treatments of lettuce seed (2). One of the marked differences between the responses of endive and lettuce seed is the greater effectiveness of the water treatments in the case of endive seed. As can be seen from Table I, with the exception of the 4-hour treatments water was quite effective and in some treatments was almost as good as thiourea in promoting germination. An-

TABLE II—SUMMARY OF DATA FROM SERIES 2. GERMINATION OF ENDIVE SEED TREATED WITH THIOUREA FOR 8 HOURS AT 18 DEGREES C. SEED TREATED NOVEMBER 10, 1944. GERMINATION OF 25-SEED LOTS WERE TESTED NOVEMBER 18, 1944 AT 32 DEGREES C. COUNTS MADE AFTER 72 HOURS

Seed Stock Number	Thiourea					Untreated Check				
	Replications					Replications				
	1	2	3	4	Total	1	2	3	4	Total
1	20	14	16	16	66	4	4	7	7	22
2	16	23	18	20	77	4	0	4	4	12
3	23	23	23	17	86	22	23	21	14	80
4	24	22	20	21	87	3	3	5	1	12
5	23	19	23	19	84	8	4	9	10	31
6	17	14	17	16	64	2	2	4	1	9
7	22	20	23	22	87	11	14	14	12	51
8	15	21	21	22	79	6	6	7	5	24
9	16	17	17	21	71	17	18	18	16	69
10	22	20	21	21	84	17	17	22	16	72
11	21	20	17	18	76	7	6	8	5	26
12	24	24	20	23	91	15	12	22	21	70
13	23	22	20	22	87	18	16	20	15	69
14	24	24	21	23	92	18	21	23	19	81
15	24	22	22	21	89	22	20	20	23	85
16	22	24	21	24	91	20	23	21	19	83
17	22	21	20	21	84	24	22	20	14	80
18	18	23	20	21	82	6	9	8	7	30
Total.....	—	—	—	—	1,477	—	—	—	—	906
Percentage	—	—	—	—	82.1	—	—	—	—	50.33

other difference between lettuce and endive seed is the capacity of endive seed to withstand a longer period of treating and at higher temperatures without showing injury to the embryos on germination. Some lots of lettuce seed (2) showed injury when treated for as much as 12 hours at a temperature as low as 18 degrees C, while no injury was observed in endive seed treated for as long as 24 hours at 25 degrees C. However, the germination was reduced when endive seed was treated at 25 degrees C for as long as 24 hours.

As in the case of lettuce seed, a 4-hour treatment is too short for maximum stimulation. The short (4-hour) treatment is less effective with water than with thiourea. The range of time and temperature for maximum results appears to be much wider with endive than with lettuce seed. About equal results with endive were obtained with 8- and 16-hour thiourea treatments at both 18 and 25 degrees C, while best results with lettuce seed required a temperature below 25 degrees and the time of treatment must not exceed 10 to 12 hours or some embryos may be injured.

Another point of interest in the data presented in Table II is the apparent difference in varieties and strains of endive seed in their capacity to germinate at temperatures around 32 degrees C without treatment. The nine lots, numbers 3, 9, 10, 12, 13, 14, 15, 16, and 17, might be considered to have germinated fairly well without treatment, considering the high temperature used. These 9 lots show an average germination of 76.6 per cent without treatment and 86.1 per cent with thiourea. This is a gain of 12.5 per cent of the untreated percentage. The nine poorest germinating lots, numbers 1, 2, 4, 5, 6, 7, 8, 11, and 18, show an average germination of only 24.1 per cent without treat-

ment but their average germination with thiourea treatment was 78.0 per cent, an increase of 223.5 per cent of the untreated percentage. The average increase in germination for the entire 18 lots which may be attributed to the thiourea treatment is 63.0 per cent of the untreated percentage.

SUMMARY

Endive seed treated with a 0.5 per cent solution of thiourea for various periods (4, 8, 16, and 24 hours) at 18 and 25 degrees C and then thoroughly dried, showed very significant increases in germination due to the treatment when they were germinated at 30 to 31 degrees after 10 days in storage at 18 to 25 degrees.

Similar lots of endive seed treated with tap-water under the same conditions as the thiourea lots also showed significant increases in germination due to the treatment. Under some conditions of treatment, water was almost as effective as thiourea in promoting germination.

For both thiourea and water, the 8-hour treatment at 18 degrees C gave the highest germination percentages. Except for the 4-hour treatment at 18 degrees and the 24-hour treatment at 25 degrees, there was little difference between treatment in the case of thiourea.

The longer periods (16 and 24 hours) and higher temperature (25 degrees) were less effective than the 8-hour water treatment at 18 degrees C. Moreover, the longer periods (16 and 24 hours) and higher temperature (25 degrees) are more likely to result in injury to embryos than the shorter periods and lower temperature.

The 4-hour period was too short to produce maximum stimulation of germination with either thiourea or water. Thiourea was much more effective than water in the 4-hour treatment at both 18 degrees and 25 degrees C.

Water was equally as effective as thiourea at the best condition of treatment (8 hours at 18 degrees C).

The 18 strains of endive seed tested exhibited great differences in their capacity to germinate at a temperature of 30 degrees C without treatment, varying from 9 to 85 per cent.

The strains that germinated poorly without treatment gave much the greatest response to the thiourea treatment. The nine strains giving the highest average germination without treatment showed an increase of only 12.5 per cent due to the treatment while the nine strains giving the lowest germination without treatment showed an average increase in germination of 223.5 per cent due to the thiourea treatment.

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A Comparison of Methods for Harvesting Experimental Plots of Cabbage[1]

By J. F. Davis, *Cornell University, Geneva, N. Y.*

NUMEROUS methods for obtaining yields of experimental plots have been used by investigators, varying from a determination of the actual plot yield to estimations of plot yields based on various plot sampling procedures. The literature on sampling techniques is voluminous, and it is not intended that the scope of this report be extended to include a general discussion of this subject. It would appear that, in general there are three approaches to the problem; *viz.*, (a) Actual plot yields; (b) yield estimates based on the relationship of the sample area to the total plot area, and (c) yield estimates based on the relationship of the sample weight to the total weight of the plot (1, 2).

Love (3) presents a very good general discussion of the subject of sampling methods for experimental plots. A method (4) of obtaining corn yields based on the selection of every fifth ear appears to have a wide range of application in harvesting experimental plots of certain types of crops.

In selecting any particular method for obtaining plot yields, a number of modifying factors should be considered, including size of plot, type of crop, type of experiment, accessibility of the experimental location, amount and kind of help available, nature of the problem under investigation, and so on. Very often a number of methods of harvest can be used that would give results of comparable accuracy; however, considerable time can often be saved in harvesting by adopting certain harvesting procedures without any resulting significant impairment of the accuracy of the data.

Procedure

Eight plots of machine-set Marion Market cabbage (100 x 15 feet) with a row spacing of 3 feet were used in this study. By planting one row in five on each plot division line the four remaining rows were available for yield determination. An attempt was made to determine the possible effect of fertility level on harvesting methods in that four of the plots received an application of 1,800 pounds of a 5–10–10 fertilizer per acre and four were unfertilized. However, no significant difference in yield between treatments was found so that no information on this point was secured.

Each individual head was weighed separately and the weight recorded in order of its position in the plot, making it possible to estimate plot yields by a number of different methods. The resulting 13 methods of harvest were as follows: actual plot yield; yields based on every third, fourth, fifth, sixth, seventh, eighth, ninth, and tenth heads; yields estimated from one, two or three rows per plot; yields based on three rows selected at random from each plot.

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[1]Journal Paper No. 672, New York State Agricultural Experiment Station, Geneva, New York, March 20, 1946.

The following procedure was used in selecting rows for obtaining yield estimate:

One row per plot — Second row
Two rows per plot — Two center rows
Three rows per plot — First three rows
Three rows random — A random selection of three rows per plot.

The mean yields and standard errors of the means for each harvesting method and the mean differences and standard errors of the mean differences between the actual plot yields and the yields obtained from the various harvesting methods were calculated and reported in Table I. The standard errors of the mean differences were obtained by pairing the data obtained from each harvesting method and the actual plot yields.[2]

TABLE I—A COMPARISON OF HARVESTING METHODS OF EXPERIMENTAL PLOTS OF CABBAGE

Method of Harvest	Mean Yield (Tons Per Acre)	Mean Difference	Standard Error of Mean Difference
Actual yield	14.85 ±1.12	—	—
Third head	14.75 ±1.07	0.10	0.188
Fourth head	14.68 ±1.15	0.17	0.149
Fifth head	14.88 ±0.98	0.03	0.162
Sixth head	14.53 ±1.11	0.32	0.275
Seventh head	14.96 ±1.12	0.11	0.265
Eighth head	14.78 ±1.36	0.07	0.315
Ninth head	15.33 ±1.13	0.48	0.208
Tenth head	15.34 ±1.01	0.49	0.242
One row	15.30 ±1.05	0.45	0.266
Two rows	15.26 ±0.87	0.41	0.263
Three rows	15.24 ±0.96	0.39	0.213
Three rows (random)	14.80 ±1.05	0.05	0.196

DISCUSSION

In a consideration of the comparable accuracies of the harvesting methods, it was assumed that the actual yield of a plot was the best yield estimate that could be made. The data in Table I indicate that a close agreement exists between the mean yields of all harvesting methods. However, it should be pointed out that, in general, the variability of the data increases when yields are calculated on less than 20 per cent of the heads. It is possible from compensating errors to obtain a mean yield by a harvesting method based on fewer heads of cabbage per plot that agrees more closely to the actual mean yield than by another method based on a greater number of heads per plot. However, this method on the average would actually be less accurate when considering the greater variability. A case in point is the situation in which the respective mean differences of 0.07 and 0.17 ton per acre are obtained based on yields estimated from every eighth head and every fourth head respectively. The respective standard errors of these mean differences are 0.315 and 0.149, indicating a greater variability for the data estimated from every eighth head. In a repetition of this

[2]This procedure was suggested by Dr. W. D. Baten, Department of Mathematics, Michigan State College, in order to account for any correlation existing between the actual plot yields and yields estimated from the various harvesting methods.

work the odds would be greater that a closer agreement would exist between a mean yield estimated from every fourth head and the actual plot yield than between a mean yield based on every eighth head.

It is interesting to note that the yields estimated from every third, fourth or fifth head are equally as accurate as yields obtained from three rows (75 per cent of the harvested plot area).

It should be pointed out that the yields estimated from the first three rows of the plot are not in as close agreement to the actual plot yields as three rows taken at random, indicating a bias (lower yield) from the fourth row of the plot. This situation in turn is reflected in the higher yields estimated from one and two rows per plot and suggests a possible advantage in a method in which samples are taken from all portions of the plot.

In deciding on the minimum number of heads or units (in the case of other crops), the size of plot should be taken into consideration, and as the size of plot decreases a higher percentage of the total plot should be used for a sample.

Practical Application

In the practical operation of harvesting heads of cabbage from an experimental plot, the following plan proved very satisfactory. First, cut every fifth head, for example, and then weigh these heads on a spring balance scale supported from a truck bed or tripod in a galvanized 1½-bushel basket with a capacity of approximately 90 pounds.

The total yield per plot is then obtained by multiplying by a suitable factor, depending on the number of heads harvested, after taking into consideration the adjustment necessary for the remaining heads not included, since the total number of heads per plot are not necessarily a multiple of the head increment used in harvest.

Summary

A comparison of methods of harvesting experimental plots of cabbage is presented in which accurate estimates of plot yields can be obtained in a number of different ways. Methods in which yield estimates are based on a certain number of heads taken in a systematic manner, *e.g.*, every fifth head, from all of the available harvest area appear to have considerable promise in facilitating harvesting operations on experimental areas.

Possible application of this procedure might be extended to such crops as sweet corn, sugar beets, or similar crops if the entire crop is harvested at one time. It would appear that in harvesting sugar beets, for example, that all of the beets in the plot could be harvested in the usual manner and every fifth beet from the various piles be taken as the sample.

This method should be very helpful in reducing the labor involved in harvesting relatively large plots from cooperative field tests with farmers. The yields could be taken and the farmer could then complete the harvest of his field in the regular manner.

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The Effect of Boron on the Vitamin C Content of Rutabagas[1]

By F. B. CHANDLER and MABEL C. MILLER, *Massachusetts Institute of Technology, Cambridge, Mass.*

THE function of boron in plant nutrition has been given much study in recent years, and although the exact role played by boron is not yet fully understood, it has been proved that the symptoms of abnormal growth in many field crops, including rutabagas, are caused by an inadequate supply of this element. The symptoms of boron deficiency may be induced by a lack of boron in the soil or, as the symptoms often occur in crops grown in overlimed or alkaline rather than in acid soils, they may be induced by an improper balance between calcium and boron, which results in reduced availability of the boron present (6, 12, 13). Furthermore, as these symptoms have been found to be more severe in dry growing seasons, a low moisture content in the soil constitutes another important factor in reduced availability of boron (2, 3). In rutabagas particularly a varietal difference is shown, the deficiency symptoms varying according to the susceptibility of the different varieties (4, 5). In 1935, MacLeod and Howatt (7) presented evidence that symptoms of abnormal growth in rutabagas are caused by boron deficiency and that the condition can be controlled by application of borax to the soil.

As the response of rutabagas to proper boron treatment is shown by improved quality and yield (2, 11) and as the roots of healthy rutabagas are good sources of vitamin C (8), the present study was undertaken to determine the effect of boron on their vitamin C content. Samples were studied both in the fresh and the dehydrated states, the dehydrated samples being studied particularly to note the effect of boron on the retention of vitamin C during drying and storage and the effect on the quality of the rehydrated product.

MATERIALS

The rutabaga roots used for analyses were obtained from Maine and Rhode Island Agricultural Experiment Stations. The Rhode Island samples were of the Macomber variety, grown on plots receiving no borax or 10, 20, or 30 pound applications of borax per acre. Those from Maine included both Macomber and Long Island Improved varieties grown on plots receiving no borax or 20 pounds of borax per acre. Maine samples were also studied that had been grown on plots with and without borax treatment as above but receiving, in addition, one ton of lime per acre. The latter samples were grown in Presque Isle and were stored at 32 degrees F from harvest until February 4, after which they were placed in cool storage until February 16, when they were analyzed. The rutabagas from Rhode Island were shipped

[1]A report on a joint project of the Office of the Quartermaster General, U. S. Army and Food Technology Laboratories, Massachusetts Institute of Technology, Cambridge, Massachusetts.

immediately after harvest and were analyzed on the day of arrival, November 16.

For the dehydration and storage studies, the rutabagas were air-dried in a tunnel dehydrator. They were then put in small friction top cans and stored at room temperature (70 to 80 degrees F) for 3 to 5 months.

METHODS

The method for the estimation of vitamin C was essentially that of Bessey and King (1) as modified by Musulin and King (10). An 8 per cent trichloroacetic acid solution containing 2 per cent metaphosphoric acid was used as the extractant. The indophenol dye was standardized according to the procedure of Menaker and Guerrant (9). The values reported for vitamin C represent the total vitamin C, *i. e.*, ascorbic acid plus dehydroascorbic acid. The moisture content was determined for all samples by the vacuum oven method, the samples being dried for 6 hours at 70 degrees C with about 30 inches of vacuum. The data on moisture content were used for calculation of the vitamin C on a dry weight basis.

RESULTS

Fresh Rutabagas: — A slight increase in the vitamin C content was shown by samples grown on plots receiving boron but no significant differences were noted between samples grown on plots with varying amounts of this element, Table I.

The roots of both varieties of rutabagas from Maine that were grown without the addition of boron were pithy and had poor flavor. In contrast, the roots from plots receiving boron had a firm texture or little pith and a fine, sweet flavor. All samples from Rhode Island showed some boron deficiency, the symptoms being most pronounced in the roots from plots that lacked boron and least pronounced in the roots from plots receiving 20 and 30 pound applications of borax. The dry period in Rhode Island during the growing season probably accounted to some degree for the development of boron deficiency symptoms in the treated samples.

There was a tendency toward a lower vitamin C content in samples grown on plots receiving lime and no boron (Table I).

The samples grown in soil treated with 20 pounds of borax per acre together with lime showed no improvement in texture and flavor over those not receiving boron. However, the samples grown in soil with lime applications alone showed a slight improvement, the Macomber and the Long Island Improved varieties being alike in this respect.

Dehydrated Rutabagas: — Rutabagas grown on plots receiving boron showed better retention of vitamin C than those grown on plots not receiving it. This effect was evident both after dehydration and after storage (Table I). The percentage retention of vitamin C after drying and storage in the Macomber variety grown in boron-treated soil was twice as much as that in the Macomber variety grown in untreated soil and nearly twice as much in the case of the Long Island Improved variety.

Rehydrated Rutabagas: — The rehydrated products from the Maine

TABLE I—TOTAL VITAMIN C IN RUTABAGAS

Treatment	Number Samples	Fresh Weight Basis Original (Mg/100 Gms)	Dry Weight Basis Original (Mg/100 Gms)	Dry Weight Basis Retained In Drying (Per Cent)	Dry Weight Basis Retained In Storage (Per Cent)	Dry Weight Basis Retained In Drying and Storage (Per Cent)	Storage Period (Months)
Grown in Maine—Macomber							
No borax no lime	1	29.0	252	29.3	57.8	16.8	3
20 pounds borax/A no lime	3	39.7	283	40.6	84.5	34.4	3
No borax 1 ton lime/A	3	29.9	237	34.0	46.2	15.9	3
20 pounds borax 1 ton lime/A	2	32.8	256	37.6	79.5	30.0	3
Grown in Maine—Long Island Improved							
No borax no lime	2	34.3	264	27.4	57.9	15.7	3
20 pounds borax/A no lime	1	49.0	288	29.4	83.1	24.4	3
No borax 1 ton lime/A	2	36.6	227	31.5	35.3	12.3	3
20 pounds borax 1 ton lime/A	2	36.3	276	35.2	60.7	21.8	3
Grown in Rhode Island—Macomber Variety							
No borax	2	28.9	241	21.6	55.6	12.7	5
10 pounds borax/A	2	31.7	289	20.9	91.5	14.2	5
20 pounds borax/A	2	36.4	296	23.6	88.0	20.5	5
30 pounds borax/A	2	35.9	289	24.8	68.8	17.1	5

rutabagas that were grown on plots treated with boron showed improved quality. Their storage life was also better, their flavor after 3 months being more like that of fresh rutabagas and their texture less pithy as compared with these characteristics in the samples grown in untreated soils and soils treated with lime. No particular differences were noted between the Macomber and the Long Island Improved varieties.

SUMMARY

A study of the effect of boron on the vitamin C content of rutabagas was made, samples being obtained from Maine and Rhode Island Agricultural Experiment Stations.

A slightly greater vitamin C content was shown by samples grown on plots receiving boron. No significant differences were noted, however, between samples grown in soils receiving varying amounts of this element.

After dehydration, rutabagas that had received boron treatment showed better retention of vitamin C during 3 and 5 months of storage at room temperature than those not receiving treatment.

The percentage retention of vitamin C after dehydration and storage was twice as great in the boron-treated samples of the Macomber variety and nearly twice as great in the boron-treated samples of the Long Island Improved variety as that in the untreated samples of these varieties.

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Further Observations on and the Application of Propagating Cabbage by Leaf Cuttings

By C. L. Isbell, *Alabama Agricultural Experiment Station, Auburn, Ala.*

A method of propagating cabbage by slips or cuttings was reported by Lindley (5) and Kendall (4) as early as 1831 and 1833, respectively. More recently, Detjen (1) and the writer (2, 3) working with cabbage-breeding programs found that vegetative methods of propagating may be helpful in increasing stock and in carrying it over seasons when the seed method is not readily applicable. Further observations in 1944 and 1945 using an impure strain resulted in additional information that should be helpful to those conducting breeding programs with cabbage.

Choice headed strains of cabbage that are being used in breeding projects are often lost in the South because they fail to seed. To test the possibility of saving such stock by vegetative means, portions of outer leaves were taken in the fall of 1944 from plants that had produced heads. These were rooted in sand in a greenhouse and grown until shoots appeared, Fig. 1 shows one of these cuttings after it had rooted but before the shoot appeared.

With several groups of cuttings it was found that, by using large leaves including axillary buds from headed plants, rapid rooting took place out of the base of the petiole and a vigorous shoot developed as the outgrowth of the axillary bud. The shoot arising as the axillary bud also rooted. Under greenhouse conditions, these developments took place within 24 days. One of these plants is shown as Fig. 2 after it had

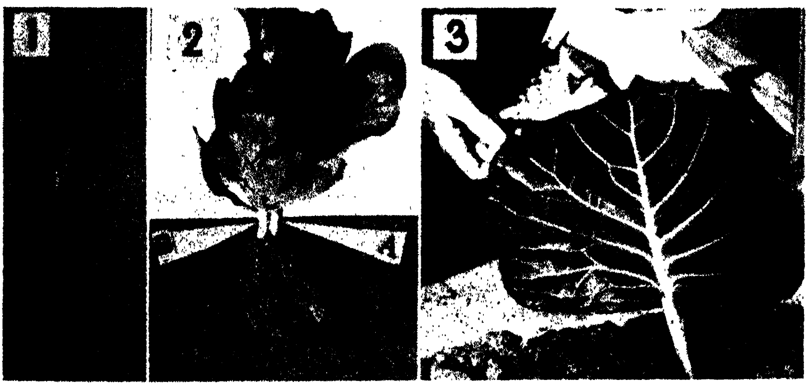

Fig. 1. Part of an old leaf used as a cutting from a headed plant after roots developed but before a shoot appeared.

Fig. 2. (A) Large or old leaf used as parent cutting; (B) vigorous shoot originating as the outgrowth of an axillary bud that was part of the parent cutting.

Fig. 3. A leaf cutting transplanted November 15 with a leaf blade spread of about 4 inches as it appeared 61 days later with a leaf spread of more than 12 inches.

been transplanted to the open, (A) being the leaf cutting and (B) the vigorous shoot developed out of the axillary bud.

With various tests it was found that leaf cuttings vary in the length of time required for roots and shoots to be produced. Variety or type appeared to influence the relative time required for roots and shoots to develop. Early-maturing types rooted and produced shoots quicker than later maturing ones. Some cuttings rooted well in 10 days, others required 15 to 20 days, and still others required longer. Some cuttings transplanted to an unheated greenhouse on November 13–15 developed shoots that appeared above the surface of the ground in 39 days. Others in a similar condition required 62 days for shoot appearance. Shoots appeared from the base of some cuttings weeks after the above ground parts of the cutting had died. This occurred in both heated and unheated greenhouses. In general, shoots appeared considerably sooner in a heated greenhouse than in an unheated one or in the open.

Leaf cuttings usually increased in size before shoots appeared. In some instances the leaf part of the cutting developed until it was as large or practically as large as a mature leaf before a shoot was differentiated. A leaf cutting was transplanted to an unheated greenhouse when the leaf spread was approximately 4 inches. Sixty-one days later (Fig. 3) the leaf spread measured more than 12 inches. This cutting made further growth and later developed shoots that produced normal heads.

Parent leaf cuttings tend to bend over to a lateral position previous to the appearance of the shoot above the surface of the ground. This is well illustrated by Fig. 4, (A). Fig. 4 (B) shows young shoots.

A leaf cutting has the ability to produce from one to many plants and heads. The number depends on the care and treatment it receives. Rooted cuttings planted in unheated ground beds in a greenhouse November 13–15 were used for observations. In the bed that received least care five out of 21 cuttings produced a total of six plants. Twelve

FIG. 4. Parent leaf cuttings (A) usually assume a lateral position previous to the time the young shoots (B) appear above the surface of the ground. This leaf cutting produced 42 plants.

FIG. 5. Part of the 42 plants produced by the parent leaf shown in Fig. 4 as they appeared under garden conditions.

out of 21 cuttings in a better cared for bed produced 30 plants. In the bed that received best care, especially with respect to watering, 15 out of 21 cuttings produced plants. Fourteen of the 15 cuttings produced 28 plants. In these three beds a total of 31 cuttings produced 64 plants. Most of the plants developed normal heads. The fifteenth cutting in the third bed mentioned was given special treatment to determine how many plants it would produce. The first shoot appeared above the ground on this cutting 57 days after planting. The new plants were removed as soon as they were large enough to transplant to pots. The first ones were removed 79 days after the cutting was planted. Within 45 days from the time the first plants were removed, a total of 40 plants were taken from this cutting. The two plants occurring on this cutting thereafter (making a total of 42 plants) were not removed but allowed to develop heads. This parent cutting is shown in Fig. 4, (A). The 40 plants removed were potted and later transplanted to the open. Part of these are shown in Fig. 5. Five of the plants were lost from one cause or another, but the other 35 developed normal, uniform plants and heads. Six heads were used for examination. The other 29 had a total head weight when harvested and trimmed of 116 pounds or an average trimmed weight of 4 pounds each. These are shown in Fig. 6.

As just pointed out, if plants are removed soon after they appear, the parent cutting has the power to produce a great number of plants. However, when no plants are removed, each cutting tends to produce 2 or 3 plants, most of which develop normal heads. This point is illustrated in Fig. 7, which shows a combined top and root view of three plants originating from one leaf cutting

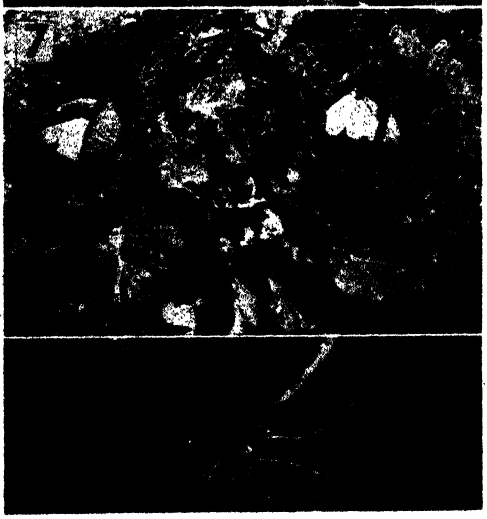

FIG. 6. Twenty-nine of the 35 heads produced from plants originating from the parent leaf shown in Fig. 4.

FIG. 7. Combined top and root views of three plants, two headed and 1 not headed, illustrating how leaf cuttings usually produce two or more plants each.

(prints made from separate negatives but same plants). It may be noted that there were two heads and one nonheaded plant attached to a common base. The total weight of these plants was 13 pounds. The heads were similar and approximately the same size, weighing just about 6 pounds each.

Leaf cuttings transplanted to the open in late fall were rather severely damaged. Most of the damage resulted from winter winds that broke the petiole of the leaf, thereby preventing or greatly limiting further growth. Similar cuttings transplanted in the same season to areas south of buildings were less severely damaged by winds, but were injured considerably by pill bugs and cutworms. However, cuttings that survived in the open and also those in protected positions developed plants that produced well-formed heads.

FIG. 8. Unlike plants arising from the same leaf cutting; (A) a nonheading type with distinct albino leaf markings, and (B) a normal pointed heading plant.

Plants originating from a single cutting tended to be very uniform, but in one instance in an unheated greenhouse the two plants originating from a single leaf cutting were very different. One of these was nonheaded with definite albino leaf marginal markings extending to the mid-rib of some leaves and in a less pronounced degree in others. Apparently, it was a definite bud sport. The other was a normal green pigmented, pointed heading type. These plants are shown in Fig. 8, (A) and (B), respectively.

SUMMARY

This paper records observations made of the development of various groups of cabbage leaf cuttings and the plants which they produced. The most important observations made were:

Part leaf cuttings, even from old or mature head leaves may be used for starting new plants. Large leaf cuttings including the axillary bud at the base of the petiole produce stronger plants more quickly. The new plant arises as the outgrowth of the axillary bud. Leaf cuttings vary greatly in the length of time required for shoots to appear. Type of cabbage, as well as environment, appears to influence the rate of rooting and the time of shoot appearance. Shoots may appear from the base of some leaf cuttings long after the above-ground part of the cutting has died.

Rooted whole leaf cuttings usually increase in size and may attain great size before shoots develop. The appearance of a new shoot on a

leaf cutting may be anticipated by the bending over or lateral position which the cutting begins to assume.

Leaf cuttings generally produce an average of slightly more than two plants each. But, if new plants are removed as they appear, a single cutting may produce more than 40 plants that develop normal heads. With good care and the right environment, most leaf cuttings or part leaf cuttings may be expected to produce plants. But, unless leaf cuttings in the open during winter months are protected against wind, they are very likely to be lost due to the petioles breaking. Plants produced from a single leaf cutting are generally uniform and normal for the strain, but one cutting was observed to produce two plants that differed so much that one was considered to be a bud sport.

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Internal Breakdown of Cabbage, as Related to Nitrogen Fertilizer and Yield[1]

By JOHN SHAFER, JR. and C. B. SAYRE, *New York State Agricultural Experiment Station, Geneva, N. Y.*

IN THE summer of 1942 there was in New York state a severe outbreak of "internal breakdown" of cabbage. Some fields of domestic cabbage were so severely affected that sauerkraut packers would not accept cabbage from them. In most years there is little or no damage caused by this "disease", but occasionally there is a year like 1942 when it causes considerable damage.

Samples of affected heads were examined by plant pathologists in 1942; there was no disease present. Therefore, it seemed that the trouble might be due to abnormal mineral nutrition. Consequently, the effect of fertilizers on the incidence of breakdown has been studied for three years. The cure for internal breakdown has not been discovered, but two factors are known to be associated with the trouble. They are here recorded for the help of others who may meet the same problem on internal breakdown in cabbage.

DESCRIPTION OF INTERNAL BREAKDOWN

Since no record has been found in the literature of any such cabbage "disease" as this which is here called "internal breakdown", a rather complete description is given. This description is based on the observation of many heads in the field. The breakdown studied is a field "disease", not a storage one. However, it may become more pronounced during storage.

The breakdown seems to start as a discoloring of the veins, these becoming a purplish-gray, accompanied by some translucency of the surrounding tissue. At this stage the leaf remains thick and fleshy as is normal of cabbage leaves. Soon, however, the affected area dies and dries down, becoming brown or brownish-black and papery. Usually the breakdown is confined to one leaf in a head. However, sometimes two or more leaves are broken down. They may be either adjacent ones, or widely separated from each other. The affected area may be small (as little as 10 square mm) and at the very edge of the leaf, or it may be large, including most of the leaf tissue. Examples were found in which only the very thick basal portion of the leaf next to the core was normal in appearance. It seems unlikely that the drying of tissue spreads, small spots becoming larger, because the vein discoloration mentioned above was not noted along the edge of a dried spot. It seems more probable that the entire area which is going to die is delimited in some way before any death of tissue occurs.

It seems probable that the dying of leaf tissue occurs only late in the summer, not long before harvest time. This impression stems from the fact that some of the dead leaves were large, approximately as large

[1]Journal Paper 671, New York State Agricultural Experiment Station, Geneva, New York.

as the neighboring live leaves. Since they would not have expanded after death, they must have died late in the season.

The leaves showing dead areas were found in many different locations in different heads. Some arose near the top of the core — young leaves; others arose near the base of the core, being only the 6th or 8th leaf in from the outside of the head — old leaves; other leaves showing dead areas were found in positions intermediate between these extremes. In no case was breakdown noted in the youngest leaves at the very tip of the core.

Experimental Observations

The two factors known to be related to breakdown are the yield, or weight of head, and the amount of nitrogen supplied to the plant.

In all, six separate field experiments have been carried out. In each of them there has been some positive correlation between yield, or weight of head, and the percentage of plants showing breakdown (see Table I). In four of the cases a fair amount of correlation is left after

TABLE I—Coefficients of Correlation between Percentage of Cabbage Plants Showing Breakdown and Weight of Heads, as Determined from Analyses of Co-variance

	1943	1944		1945		
r-error	0.319	0.264*	0.315	0.074	0.495	0.086
r-total	0.610**	0.490**	0.521**	0.348*	0.619**	0.247

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

the effects of replicates and treatments have been removed by an analysis of co-variance.

It is assumed that the heavier heads show more breakdown because of some growth condition which causes them to grow large, and at the same time makes them more susceptible to breakdown. It has been suggested that this internal breakdown of cabbage has some similarity to tip-burn of lettuce, and is caused by a temporary water shortage. If so, one might assume that the heavier heads have grown more rapidly than the lighter heads and are therefore softer and more susceptible to injury by a water shortage.

The amount of nitrogen supplied to the crop is connected with the percentage of heads showing breakdown. The larger the amount of nitrogen, the higher is the percentage of breakdown. (See Table II). The results obtained in 1943 and 1945 agree on this point; the effect of nitrogen on the incidence of breakdown was significant at the 1 per cent level in both years.

Apparently at least part of the effect of nitrogen on breakdown is a direct effect. In this connection, note that in 1945 increased nitrogen supply caused increased breakdown without any consistent or significant increase in yield (*cf.* especially 5–10–5 and 10–10–5).

The relation of phosphorus and potassium to the breakdown is not clear at present. Magnesium, manganese, zinc, copper and boron in the amounts used do not stop the appearance of the breakdown.

TABLE II—RELATION OF NITROGEN CONTENT OF THE FERTILIZER TO YIELD AND TO PERCENTAGE OF CABBAGE HEADS SHOWING INTERNAL BREAKDOWN

Fertilizer Ratio*	Yield (Tons Per Acre)	Per Cent Breakdown
	*Season of 1943***	
5-10-15	21.7	11.2
15-10-15	24.1	20.5
15-10-15+20 lbs. Borax	23.6	24.4
15-10-15+20 lbs. Borax	23.4	18.[illegible]
	Season of 1945†	
0-10-5	15.8	8.53
5-10-5	17.6	9.47
10-10-5	16.6	16.10
5-10-10	15.6	6.04
10-10-10	16.4	12.46

*All fertilizers were used at a rate of 1,000 pounds per acre.
**For the 1943 data, each figure is the average from two plots.
†For the 1945 data, each figure is the average from four plots.

The only practical recommendation is that, at least in New York State, cabbage should not be supplied excessive amounts of nitrogen.

The Influence of Rainfall on the Response of Cantaloupes to Manures and Commercial Fertilizers

By E. M. Rahn, *University of Delaware Agricultural Experiment Station, Newark, Del.*

THERE is much debate among growers as to the relative value of animal manures and commercial fertilizers in cantaloupe production. The results of an experiment conducted in Sussex County, the center of the cantaloupe section on the Delmarva Peninsula, indicate that rainfall has much to do with this question. Consideration of 2 years' results of an extensive 4-year experiment allows a study of the response of cantaloupes to manures and fertilizers under extreme conditions of rainfall. The first year, 1941, was one of abundant and well-distributed rainfall while the last year, 1944, was one of extreme drought.

Experimental Methods

The methods of culture used were similar to those used by growers. About a month before seeding the latter part of April, manures were placed in furrows about 8 inches deep and covered. The stable manure used was partially decomposed horse manure and the mushroom manure used was a mixture of decomposed horse manure and soil as taken from mushroom houses. Chicken manure was broiler manure with peanut hull litter. The analyses of these manures are given in Table I. Commercial fertilizers were applied at seeding and as a side-dressing just before the plants started to "vine-out." They were applied in bands in furrows 3 inches deep and 6 inches from the row. Seed of Jumbo Hale's Best variety was planted in rows 6 feet apart. Plants were ultimately thinned to stand 2 feet apart in the row. Each treatment was replicated five times in a randomized-block arrangement and each plot consisted of three 50-foot rows. Only the center row was used for taking yield records.

TABLE I — Analyses of Manures Used (Percentages Based on Weight When Applied)

Year	Nitrogen (N)			Phosphorus (P_2O_5)			Potash (K_2O)			Moisture		
	C.M.*	S.M.**	M.M.†	C.M.	S.M.	M.M.	C.M.	S.M.	M.M.	C.M.	S.M.	M.M.
1941	0.48	0.41	0.40	Trace	Trace	Trace	0.35	0.37	0.47	38	67	34
1944	0.98	0.30	0.70	0.77	0.14	0.50	0.57	0.19	0.55	38	82	37

*C.M. = Chicken Manure.
**S.M. = Stable Manure.
†M.M. = Mushroom Manure.

Results and Discussion

Rainfall records taken near the site of the experiment are given in Table II for the months of June and July, the critical months with regard to rainfall in cantaloupe production. It can readily be seen that these months in 1941 with 4.40 inches of rainfall above average were relatively "wet," while in 1944 with 4.44 inches below normal they were "dry."

TABLE II — RAINFALL FOR JUNE AND JULY IN 1941 AND 1944

Rainfalll	1941 (Inches)			1944 (Inches)		
	June	July	Total	June	July	Total
1941 and 1944	4.32	7.78	12.10	2.50	0.76	3.26
Average, 1934 to 1943, inclusive	3.13	4.57	7.70	3.13	4.57	7.70
Difference	+1.19	+3.21	+4.40	-0.63	-3.81	-4.44

This difference in rainfall was reflected in differences in yields of cantaloupes as recorded in Table III. The yields of marketable cantaloupes in the "wet" season for the various treatments were two to six times higher than in the "dry" season. Furthermore, manures, chicken manure excepted, were necessary for high yields in the "dry" year but not in the "wet" year, commercial fertilizers alone being sufficient. Probably the added value of the manure in the furrow in the "dry"

TABLE III — YIELDS PER ACRE AND PER CENT STANDS OBTAINED IN CANTALOUPE FERTILIZER EXPERIMENT IN 1941 AND 1944

Treatment (Application Per Acre)	No. of Marketable Melons		No. of Early* Marketable Melons		Number of Jumbos**		Percentage of Stands	
	"Wet" Year 1941	"Dry" Year 1944	"Wet" Year 1941	"Dry" Year 1944	"Wet" Year 1941	"Dry" Year 1944	"Wet" Year 1941	"Dry" Year 1944
No fertilizer or manure	3,194	610	436	0	387	0	86	91
0-10-5, 700 pounds, bands 0-10-5, 400 pounds, sidedressing	5,924	1,830	2,836	290	1,617	58	94	97
5-0-5, 700 pounds, bands 5-0-5, 400 pounds, sidedressing	6,602	494	3,320	29	1,617	58	88	98
5-10-0, 700 pounds, bands 5-10-0, 400 pounds, sidedressing	5,295	1,336	2,439	436	1,355	87	89	77
5-10-5, 700 pounds, bands 5-10-5, 400 pounds, sidedressing	6,495	1,510	2,575	145	2,217	261	90	96
5-15-5, 700 pounds, bands 5-15-5, 400 pounds, sidedressing	6,389	1,394	3,098	261	1,849	87	88	87
5-10-10, 700 pounds, bands 5-10-10, 400 pounds, sidedressing	6,244	1,276	3,165	116	1,839	116	87	93
5-10-15, 700 pounds, bands 5-10-15, 400 pounds, sidedressing	7,134	1,452	3,252	203	2,449	232	85	94
Stable manure, 10 tons, in furrow	5,827	2,614	1,123	1,539	1,326	174	89	92
Stable manure, 10 tons, in furrow 5-10-10, 700 pounds, bands	6,369	2,033	2,343	900	1,800	203	78	93
Mushroom manure, 10 tons, in furrow	5,363	2,846	1,210	1,859	1,249	407	87	88
Mushroom manure, 10 tons, in furrow 5-10-10, 700 pounds, bands	6,824	2,643	2,488	1,452	1,926	494	86	70
Chicken manure, 5 tons, in furrow	6,582	987	2,120	261	1,675	348	87	43
Chicken manure, 5 tons, in furrow 5-10-10, 700 pounds, bands	6,621	2,091	2,448	1,220	1,462	87	77	68
2-8-16, 700 pounds, bands Chicken manure, 2½ tons, sidedressed	7,299	1,771	2,778	116	2,333	203	89	92
Difference required for significance	1,413	921	1,343	820	740	Not sig	13	19

*Yield during first 10 days of harvest season.
**Jumbos are melons 5 inches or more in diameter.

year was associated with its high water holding capacity. The respective marketable yields of the best mushroom manure, stable manure, chicken manure, and commercial fertilizer treatments in the "dry" year were 2846, 2614, 2091, and 1830 melons while in the "wet" year they were 6824, 6369, 7299, and 7134 melons per acre. The latter yields indicate that when moisture is not limiting, chicken manure when used as a sidedressing in conjunction with a fertilizer of 1–4–8 ratio at planting time or a fertilizer of 1–2–3 ratio used at planting and for sidedressing produced the highest yields.

Further evidence of the importance of rainfall in evaluating cantaloupe fertilizer practices is the fact that a fertilizer application supplemental to stable and mushroom manure was of value in the "wet" but not in the "dry" year. In fact, the yields were somewhat, though not significantly on statistical grounds, depressed by its use in the latter case. In the "wet" year the additional fertilizer could be used, while in the "dry" year soil moisture was the limiting factor, not soil fertility, and possibly the somewhat lower yields were due to excess or unbalanced fertilization.

Significant too was the fact that chicken manure was very effective in the "wet" year, especially when applied as a sidedressing, but not in the "dry" year, particularly when placed in the furrow without any supplemental fertilizer application. In the former case the yield was 7299 melons per acre, the highest yielding treatment in the "wet" year, while in the latter case it was only 987 melons per acre, one of the poorest yields. Chicken manure in the furrow in a season of low rainfall proved to be hazardous, while applied in sidedressing gave a fair yield for an extremely dry season, 1771 marketable melons per acre.

Rainfall records were important in the evaluation of fertilizer ratios. In the "wet" year the respective yields from the four ratios, 1–2–0, 1–2–1, 1–2–2, and 1–2–3 were 5295, 6495, 6244, and 7134 melons per acre, indicating that increased potash applications were of value. In the "dry" year no such response occurred. In the "wet" year the respective yields from 0–2–1 and 1–2–1 ratios were 5924 and 6495, indicating an appreciable but not statistically significant response to nitrogen. In the "dry" year, there was no response. In the "wet" year the respective yields from 1–0–1, 1–2–1, and 1–3–1 ratios were 6602, 6495, and 6389, indicating no response to phosphorus. In the "dry" year, the corresponding yields were 494, 1510, and 1394, indicating a large response to phosphorus from the first increment which might be attributed to greater fixation in the "dry" season. In other words, in the "wet" year the 1–2–3 ratio was best while in the "dry" year the 0–2–1 and 1–2–1 ratios were superior. These facts indicate that of the three major fertilizer elements, potash was especially responsive to high rainfall. They also indicate that variations of the fertilizer ratios in the "wet" year affected yields much more than in the "dry" year, provided a minimum of 110 pounds of P_2O_5 per acre had been added first.

Analysis of the early marketable yields in Table III indicates relationships similar to those of total yields between rainfall, treatments, and yields. Such was also the case with yields of jumbos, melons 5 or more inches in diameter, except that in the "dry" year yield differences

were not statistically significant. The only significant relationship between rainfall and percentage of stands as recorded in Table II occurred when chicken manure was placed in the furrow. In the "wet" year the stand was 87 per cent while in the "dry" year it was 43 per cent. This was due to a prevention of the accumulation of soluble salts in the seedling zone.

Conclusions

A study of the yield records of a cantaloupe fertilizer experiment in a year of high and one of low rainfall reveals not only that the yields were several times higher in the "wet" year but also that the treatments arranged themselves in very different orders in the 2 years. Therefore, cantaloupe fertilizer recommendations cannot be dogmatically made without considerable regard to rainfall. Manures in the furrow, chicken manure excepted, were essential for high yields in the "dry" year but not in the "wet" year, commercial fertilizers alone being sufficient. The value of the manure in the "dry" year was attributed to its water-holding capacity. Supplementing manures, chicken manure excepted, with commercial fertilizers was of value in the "wet" year only. Chicken manure was very effective in the "wet" year, especially when applied as a sidedressing, but not in the "dry" year. Of the three major fertilizer elements, potash was especially responsive to high rainfall, and a 1–2–3 fertilizer ratio was best in the "wet" year. Early yields and yields of jumbos were affected similarly to total yields. Chicken manure when placed in the furrow had an adverse effect on percentage of stand in the "dry" year only.

The above conclusions apply only in seasons of extremely high or low rainfall. However, they are of value as guideposts for making recommendations for the usage of manures and fertilizers in cantaloupe production. In a practical sense, the grower desires a fertilization program that will produce the highest possible yields every season whatever the rainfall might be. Therefore, it would seem logical to recommend to growers that on soils similar to those used in this experiment they use stable or mushroom manure in the furrow supplemented with a 1–2–3 commercial fertilizer ratio. If chicken manure is more available than other manures, it should be used as a sidedressing after an application of high-potash fertilizer at seeding. If no manure is available, then the use of a fertilizer with a 1–2–3 ratio would seem advisable.

The Development of Powdery Mildew Resistant Cantaloupes

By DEAN E. PRYOR, THOMAS W. WHITAKER, *U. S. Department of Agriculture, La Jolla, Calif.*, and GLEN N. DAVIS, *University of California, Davis, Calif.*

CANTALOUPE powdery mildew (*Erysiphe cichoracearum* DC.) unless controlled by fungicides or through the use of mildew-resistant varieties, is a limiting factor in the production of cantaloupes and other melons in some of the irrigated valleys of the Southwest. Many fungicides, various cultural practices, and miscellaneous nostrums have been employed in attempts to control the disease, but all of these measures failed to provide satisfactory relief. When these control methods proved futile, the development of disease-resistant varieties seemed to offer a logical approach to the ultimate solution of the problem. Accordingly, in 1926 the U. S. Department of Agriculture and the California Agricultural Experiment Station instituted a cooperative breeding program shortly after mildew became prevalent in the Imperial Valley of California.

Recently Middleton and Yarwood (3) have completed a comprehensive series of tests of some of the new organic fungicides and copper-containing spray materials. They find that powdery mildew can be controlled by certain of these materials alone or in combination, if attention is given to the following points: (a) correct dosage; (b) proper time of application, and (c) adequate leaf coverage, which necessitates the use of good spray equipment. However, if resistant varieties are available they are more satisfactory than the susceptible if in addition they are commercially acceptable.

It is the purpose of the present paper to show in some detail the methods and procedures used in the development of powdery mildew resistant varieties of cantaloupes which are acceptable to the grower, shipper, and consumer. The initial results of this program, which culminated in the release of Powdery Mildew Resistant Cantaloupe No. 45 to the industry in 1935, have been summarized by Jagger and Scott (1).

In 1938 a new race of *Erysiphe cichoracearum* (designated as race 2) appeared, to which all commercial cantaloupes, including No. 45, were very susceptible (2). With this disturbing occurrence the problem reverted to its original status. Stated briefly and with some oversimplification it consisted in locating genes for resistance to both races and combining them with those factors that are instrumental in producing good vine and fruit characteristics.

The appearance of a second race of mildew on cantaloupes required considerable alteration in breeding and testing techniques, and more complete information regarding the biology of the parasite appeared to be essential.

THE PARASITE

Erysiphe cichoracearum is composed of numerous biotypes which attack a large number of host species in a great many families. Un-

doubtedly there are overlappings in the host ranges of many of these races. Furthermore, since the sexual stage occurs occasionally in some of them, variation may result from natural hybridization. It was therefore not surprising when a new race of the fungus appeared shortly after Powdery Mildew Resistant Cantaloupe No. 45 was introduced. Likewise, other troublesome races or variants may be expected to appear in the future.

The ability of certain powdery mildews to develop under conditions of low humidity (8) peculiarly adapts them to the arid climate of the Southwest. In fact, high humidity may actually be detrimental. At least, it is known that high humidity favors growth of certain fungus parasites of the powdery mildews and that rainfall, through mechanical action, materially decreases disease incidence. Yarwood (9) has shown that some powdery mildews may even be controlled under experimental conditions by vigorously spraying infected leaves with water from an ordinary garden hose. Field observations show that the fungus is seldom found on cantaloupes in the Imperial Valley during the very hot weather of summer and early fall, while laboratory experiments indicate that a continuous temperature of 95 degrees F for a few days in many cases kills the fungus growing on detached leaves.[1]

These observations suggest three features essential to the success of the breeding program: (a) the maintenance of a constant watch for new races of the fungus; (b) development of a controlled method of producing uniformly severe infection and progress of the disease on test plants; and (c) the collection of a large number of types and varieties of the host species as potential sources of resistant individuals.

Testing for Resistance

Six-inch pots in the greenhouse are planted with 4 to 6 seeds per pot. When the first true leaves have unfolded, the plants are placed in a shaded glass-sash chamber (4). Conidia from heavily infected leaves are then blown over the plants. Considerable infection can be obtained by simple dusting or by leaf contact, but results have been found to be more uniform with the blowing method. It is not necessary to wet the plants or the walls of the chamber to secure adequate infection. After 18 to 24 hours, plants are removed from the chamber. Within 16 days after inoculation, readings of a reasonable degree of accuracy can be made on powdery mildew resistance (5). For convenience in recording the results of greenhouse trials, five classes or categories of resistance have been arbitrarily established, based on extent of mycelium and degree of sporulation: 0 designating no mycelium visible to the naked eye and 1, 2, 3, 4, designating increasingly abundant mycelial development and conidial production. The letter *A* is employed in conjunction with the numerical rating to indicate chlorotic or necrotic spotting associated with the organism. This latter symptom was usually evident only on the more resistant individuals.

Since elimination of susceptible plants can be made in the greenhouse about a month after the seed is planted, the time and space required for field plantings can be materially reduced (5). However,

[1]Unpublished data.

field trials are essential for determining fruit and vine characteristics together with mildew resistance under conditions comparable to those of commercial plantings.

SOURCES OF MATERIAL

From a survey in which 21 species in 11 genera of the Cucurbitaceae were tested for resistance to race 2 of the mildew (7), it was found that seven species had a consistently high level of resistance; 10 were intermediate or contained individual plants high, intermediate, or low in resistance; and 4 had a consistently low level of resistance. No plants in any species were found with a higher degree of resistance than that occurring in the most resistant plants of *Cucumis melo*. These observations seem to indicate that the related species observed are no more promising as sources of resistance than is *C. melo*. In addition, it has been shown that *C. melo* cannot be crossed successfully with other species of the Cucurbitaceae (6). As a result, the search for resistant genes has been primarily restricted to *C. melo*.

As potential sources of disease-resistant genes there should be available for investigation a wide range of material, preferably from endemic sources, that will adequately represent the variation found within the species. Through the efforts of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, an extensive collection of *Cucumis melo* from India, Russia, Afganistan, Iran, and adjacent regions has been accumulated.

From the point of view of the plant breeder and plant explorer it is of considerable importance to know the general regions from which collections can be made that are likely to have resistant genes. Resistant importations obtained to date are listed in Table I together with countries of origin and brief descriptions of the fruits. Two points are evident from this table: (a) the mildew-resistant collections without exception have originated in India, and (b) the fruit type is extremely

TABLE I—POWDERY MILDEW RESISTANT IMPORTATIONS OF *Cucumis melo* L.

Year Imported	Accession Number	Country of Origin	Description of Fruit
1927	Calif. 525	India	Oblong; ribbed; with a slight netting; flesh mealy, unpalatable.
1929	P. I. 79374	India	Greyish green; no rib; trace of net; cracks at maturity; flesh white, juicy, unpalatable; no sugar.
1936	P. I. 115908	India	Elongated; ridged; tough rind; trace of net; flesh deep salmon orange, juicy, slightly mealy, edible.
1936	P. I. 115935	India	Snake melon type, 1 to 2 feet long, nearly straight; barely perceptible longitudinal ridges; smooth; splits at maturity; rind greyish green, turning to light grey when ripe; flesh white, dry, mealy, unpalatable.
1937	P. I. 124111	India	Flat; green; shallow sutures with dark green stripes in each suture; cracks and turns yellow at maturity; smooth; flesh white, somewhat mealy, dry, unpalatable.
1937	P. I. 124112	India	Oblong, greyish green with dark green stripes in each suture, cracks and turns yellow at maturity, smooth; flesh white, somewhat mealy, dry, unpalatable.
1941	P. I. 134192	India	Blotchy, dark green skin, smooth-mottled; turns yellow and cracks at maturity; flesh pale pink, coarse, stringy, unpalatable.
1941	P. I. 134197 P. I. 134198 P. I. 134199 P. I. 134200	India	Snake melon types, 2 to 3 feet long; greyish green; smooth, slight ridges; crack at maturity; flesh white, dry, mealy, unpalatable.

FIG. 1. Typical examples of the primitive, heterozygous Indian melons in a trial from which genes for resistance to powdery mildew were obtained. Note the cracking or splitting at maturity, the smooth, unnetted skin, and irregular shapes. At left for comparison are two cantaloupes of the Hale's Best type.

primitive in character as evidenced by the smooth unnetted skin, the tendency to crack or split at maturity, and the dry, generally mealy and unpalatable quality of the flesh (see Fig. 1).

The degree of resistance in individual plants of this material and in subsequent progenies ranges from complete absence of microscopically visible signs of mildew on leaves, stems, and cotyledons to abundant disease development on all of those organs. When susceptibility is intermediate, there is a direct correlation between the amount of mildew on leaves and on stems; but when plants are only slightly susceptible, or slightly resistant, no correlation is found between the degree of infection on leaves and on stems.[1] Cotyledons, in general, seem to be more readily attacked by the parasite than the other organs. This observation appears to hold true not only in *Cucumis melo* but also in most species of the other genera tested.

In the search for individual plants carrying genes for resistance to powdery mildew some 1400 lots of seed have been tested, using the technique described previously. Of this total, 526 lots were recent importations made by the Division of Plant Exploration and Introduction. The latter material contained five importations that carried mildew resistant factors, P.I. Nos. 134192, 134197, 134198, 134199, and 134200 (see Table I). Of stocks accumulated up to 1939, six carried resistant factors and several seemed to be practically immune.

[1]Unpublished data.

The material from all sources was extremely heterozygous, individuals from some single seed lots ranging on our scale of disease severity from 0 (very resistant) to 4 (completely susceptible).

The Development of Commercially Acceptable Cantaloupes Resistant to Powdery Mildew Races 1 and 2

The procedure has been to identify and isolate for selfing, plants showing the greatest ability to withstand mildew attacks, and by this method eventually to obtain through inbreeding and selection individuals that are homozygous for resistance. In conjunction with this plan, a series of crosses and backcrosses between commercial types and the most resistant material is initiated. The progeny from each cross or self is tested in the greenhouse for disease resistance, and the most resistant individuals are given a field trial to determine their fruit and vine characteristics, as well as to obtain their mildew reaction under field conditions. When a strain approaches the desired level of mildew resistance, a large planting is made for increase and for rigorous selection of desirable fruit and vine types under commercial conditions. By employing spring crops in the Imperial Valley, and summer crops at Davis and Torrey Pines, two generations can be grown each year:

As a result of this program Powdery Mildew Resistant Cantaloupe No. 5 was released to seedsmen and growers in 1942, and No. 6 and No. 7 in 1944. These strains possess a much higher level of resistance to race 2 than does No. 45 (see Table II and Fig. 3), although they cannot be considered as immune from powdery mildew. Their genetic relationship is shown in Fig. 2, while the detailed pedigrees are listed below.

TABLE II—The Reaction of Powdery Mildew Resistant Cantaloupe No. 5, 6, 7, and 45, to Race 2 of the Parasite. (The Figures Indicate the Number of Plants in Each Disease-Resistance Category

Disease Index	First Planting**			Second Planting**			Third Planting**			Disease Index Average for Three Plantings
	0	2	4	0	2	4	0	2	4	
Variety	*Field Reaction**									
No. 5	2	85	5	0	89	3	81	10	0	1.45
No. 6	20	64	0	19	73	0	83	6	0	1.08
No. 7	3	88	0	0	92	2	7	93	2	1.95
No. 45	0	0	89	0	0	90	0	0	94	4.00

Disease Index	Leaves					Cotyledons		Stems		
	OA	1	1A	2	4	OA	4	0	OA	4
Variety	*Greenhouse Reaction**									
No. 5	18	1	3	1	0	23	0	22	1	0
No. 6	32	0	3	0	0	35	0	34	1	0
No. 7	5	0	9	2	0	14	2	15	1	0
No. 45	0	0	0	0	40	0	40	0	0	40

*Disease index based on amount of mycelium, degree of sporulation, and presence or absence of necrosis or chlorosis: 0 = no mycelium; 1 = very slight amount of mycelium; 2 = slight mycelium sporulation usually suppressed; 3 = medium mycelium, sporulation usually somewhat suppressed; 4 = abundant mycelium, sporulation vigorous; A = presence of necrosis or chlorosis. Notes on necrosis were not taken in the field because this symptom was difficult to separate from that caused by agents other than powdery mildew.

**First planting, Dec. 29, 1943; notes, June 7, 1944. Second planting, Dec. 29, 1943; notes, June 14, 1944. Third planting, Jan. 31, 1944, notes, June 15, 1944.

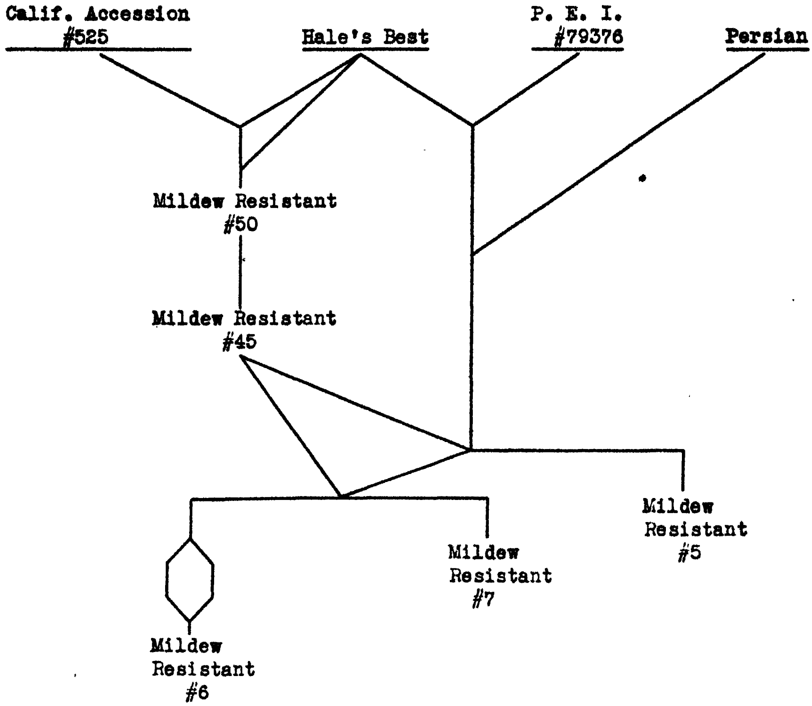

FIG. 2. The interrelations of the powdery mildew resistant cantaloupes.

DETAILED PEDIGREES

No. 5

Step 1. Resistant melon (P.I. No. 79376) crossed with Hale's Best.
Steps 2 to 5. Selfed and open-pollinated for four generations.
Step 6. Resistant selection crossed with Persian.
Steps 7 to 12. Selfed and open-pollinated for 6 generations.
Step 13. Resistant selection crossed with No. 45.
Steps 14 to 20. Selfed and open-pollinated for seven generations.
Step 21. Released as Powdery Mildew Resistant Cantaloupe No. 5.

No. 6

Step. 1. Selection from F_1 of Step 13 above.
Step 2. Open-pollinated selection.
Step 3. Self-pollinated selection.
Step 4. Backcrossed to No. 45.
Steps 5 to 7. Selfed for three generations.
Step 8. Crossed two selected siblings.[1]
Steps 9 to 10. Selfed for two generations.
Step 11. Released as Powdery Mildew Resistant Cantaloupe No. 6.

[1]Prof. Edgar Anderson has provided the theoretical basis for the efficiency of such crosses (see Anderson, Edgar. "Recombination in species crosses". *Genetics* 24; 668–698. 1939).

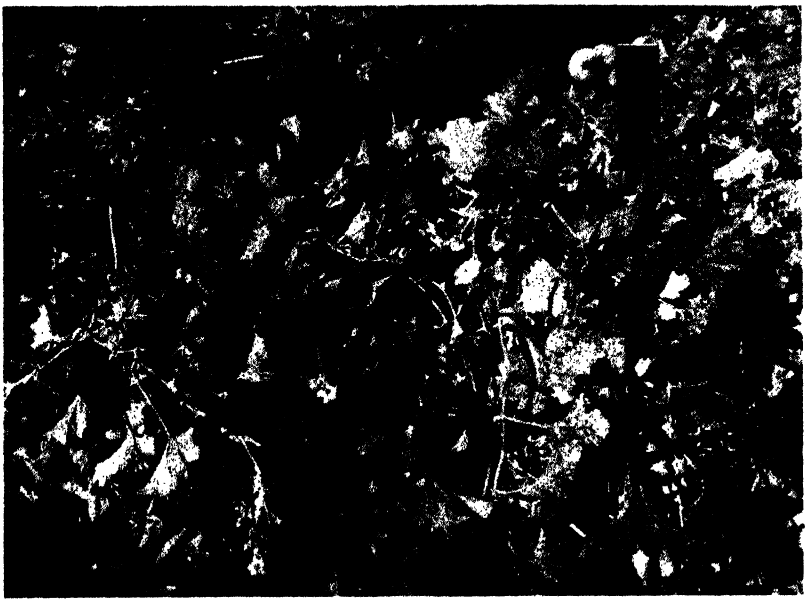

FIG. 3. Vines of Powdery Mildew Resistant Cantaloupe No. 5 and No. 45. (1) Heavily mildewed vines of No. 45. (5) Healthy vines of No. 5. These vines were growing side by side in the bed and were intertwined. It was necessary to untangle them before the photograph could be made.

No. 7

Step 1. F_2 selection from Step 4 in pedigree of No. 6.
Step 2 to 5. Selfed and open-pollinated for four generations.
Step 6. Released as Powdery Mildew Resistant Cantaloupe No. 7.

DESCRIPTION OF POWDERY MILDEW RESISTANT CANTALOUPES No. 5, No. 6, AND No. 7

Powdery Mildew Resistant Cantaloupe No. 5 makes a heavy vine growth with dark green leaves (see Fig. 3). Under good cultural conditions it has produced over 200 crates to the acre (a yield of 150 to 175 is considered good). The melon has a large stem scar and a fine, low net which does not entirely cover the sutures (Fig. 4). In the judgment of many individuals connected with the industry, No. 5 has the best eating quality of any melon that has ever been shipped from the Imperial Valley. This high quality is reflected in refractometer readings of 13 to 14 per cent soluble solids (mostly sugars). The flesh is soft, and the edible portion extends almost to the rind. Shipping tests indicate that No. 5 is fully equivalent in this important character to any of the melons arriving on the New York market.[1] However, the variety possesses certain undesirable features, some of which can

[1]This observation was made by Dr. J. S. Wiant, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering.

be eliminated by further selection. It is not as early as some other varieties, nor is it completely immune from mildew. The melons are somewhat variable in size and during mid-season are a little too large, running to Jumbo 45's and 36's. Slight "sugar crack" development at the stem end of some fruits is objectionable in itself but seems to be associated with high sugar content. If the melons are not harvested at the first indication of the "slip", they tend to become over-mature rather quickly. When inexperienced labor must be used, this feature is a decided disadvantage. Since its release in 1942 this variety has constituted a large portion of the Imperial Valley crop.

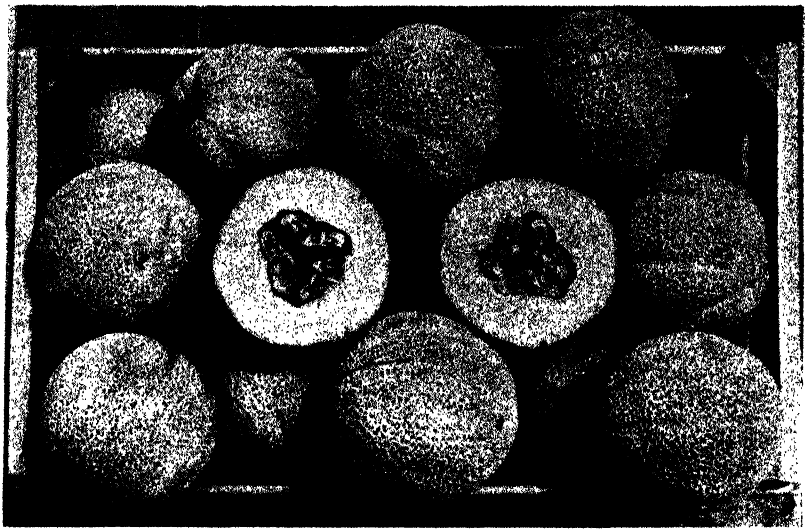

FIG. 4. Powdery Mildew Resistant Cantaloupe No. 5. Note the thick flesh, edible to the rind; rather fine even net; large abscission scar; tendency to "sugar crack" at sutures, near the abscission scar.

Powdery Mildew Resistant Cantaloupes No. 6 and No. 7 are similar in their pedigree to No. 5 except that they have been backcrossed to No. 45 one more time. They are also similar in vine characteristics, but No. 6 and No. 7 have slightly different fruit characters and date of maturity. No. 6 has a small button-like protrusion at the blossom end of the fruit (see Fig. 5). It is well netted, well shaped, and of very attractive exterior appearance. However, it has a larger seed cavity than No. 5, and the flesh has less quality and flavor. No. 7 produces a small, oblate melon (see Fig. 6) and in comparison with No. 5 and No. 6 is somewhat later in maturity. The seed cavity and flesh are comparable to No. 6.

SUMMARY

Cantaloupes of very good commercial quality and of a high level of resistance to cantaloupe powdery mildew (*Erysiphe cichoracearum* D C., races 1 and 2) have been developed by incorporation of resistant

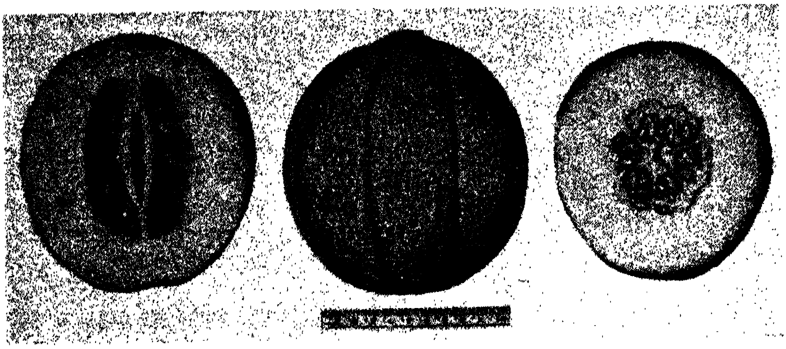

FIG. 5. Powdery Mildew Resistant Cantaloupe No. 6. The slight button-like protrusion at the blossom end of the fruit is characteristic of this strain.

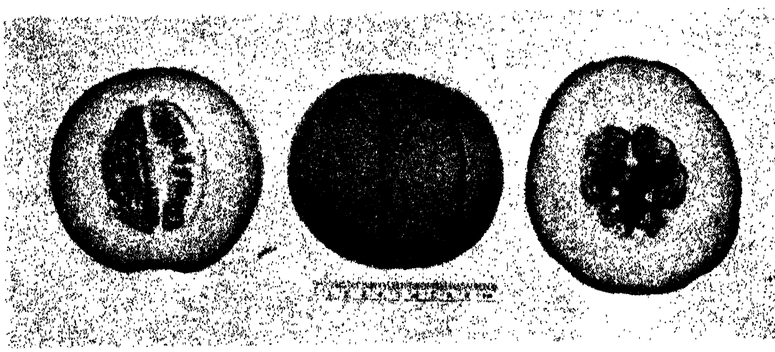

FIG. 6. Powdery Mildew Resistant Cantaloupe No. 7. Note the somewhat flat shape of the melon. When planted in comparable trials with No. 5 and No. 6 it tends to be smaller in size and later in maturity.

genes, imported in *Cucumis melo* from India, into susceptible commercial types. By successive crossing and backcrossing to the commercial varieties, combined with rigid selection for fruit and vine type, resistant strains have been produced which are equal to, if not superior in most respects, to susceptible, commercial varieties. The techniques and procedures used in this program are described in detail.

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The Development of Downy Mildew-Resistant Cucumbers[1]

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Downy mildew is perhaps the most important disease attacking cucumbers in South Carolina. It usually appears in the Charleston area about the time harvesting begins. The destructiveness of the disease depends on weather conditions following the initial infection which is caused by spores brought in by wind currents from southern cucumber areas such as North Florida. Nusbaum (3) found that the disease may be controlled by careful application of certain copper fungicides. Although this method of control is satisfactory, it involves considerable labor and expense and most growers do not use it.

Prices of cucumbers are very good during October and a small acreage can be grown for marketing at this time by dusting at 5 day intervals as recommended by Clayton (1). In spite of this expensive dusting program, mildew always kills the vines prematurely and yields are so low as to border on the line of unprofitable production. A few plantings have been lost because weather conditions were unfavorable for dusting at the proper time. Jenkins (2) reported all commercial varieties susceptible to mildrew while certain P.E.I. accessions from China, India, and Puerto Rica possessed some degree of resistance. It therefore appeared that the only practical solution to the problem was through a breeding program.

In 1939 crosses were made between two downy mildew-resistant cucumbers, Puerto Rico 37 and Chinese Long, and the commercial variety A & C. After several generations of inbreeding the progenies of these crosses, strains were found in which resistance approaching that of the resistant parent was combined with fruit type approaching that of the commercial varieties. In the meantime, two new varieties, Cubit and Marketer, were introduced, and it was considered desirable to combine the excellent fruit types of these two varieties with mildew resistance.

During the spring of 1943 crosses were therefore made between Puerto Rico 40 and Cubit and Marketer. Two generations of the progenies of these crosses have been grown each year so that the F_5 was under observation in the fall of 1945.

The methods used were essentially those described by Shifriss (4). Selections for resistance were made on the basis of field performance.

Downy mildew appeared early in the 1945 spring crop and caused serious damage to the commercial plantings. Vines of all commercial varieties growing on the station plots were killed in June, whereas most of the resistant progenies continued to grow profusely until they were plowed in during the first half of August.

All observations point to the fact that the resistant progenies carry a high degree of resistance but are not immune to infection. When the vines become old and weakened, infection occurs on the older leaves

[1]Technical contribution No. 134 from the South Carolina Agriculture Experiment Station.

that have begun to deteriorate. The lesions formed on the leaves of resistant types were small and in most cases sporulation was very sparse. In view of these observations it may be expected that when entire fields are planted to the resistant types, development of the disease will be almost entirely prevented.

Mildew inoculum is present when the fall crop is seeded, and commercial varieties succumb to it before or shortly after fruiting begins. In contrast with this, the resistant progenies grew throughout the fall of 1944 and 1945, although no fungicide applications were made. Not only was a profitable crop of cucumbers harvested and marketed, but the vines continued growth to mature fruits that had been selfed. In 1945, the commercial varieties planted as checks produced a few marketable fruits the first week of harvest but stopped fruiting and growth completely by the end of the second week. In contrast, plants of the resistant progenies continued production of marketable fruit over a period of four weeks.

The fruit type of many of the resistant progenies approaches very closely that of Marketer and Cubit. (Fig. 1.) A little segregation in type and resistance was evident in the F_5 generation grown during the fall of 1945, but it is believed this can be eliminated in one more year.

In order to obtain some information on the productivity of the resistant progenies, seed of open-pollinated fruits was harvested in the spring of 1945. These seed were planted in a randomized block yield test in comparison with commercial varieties. Although the planting

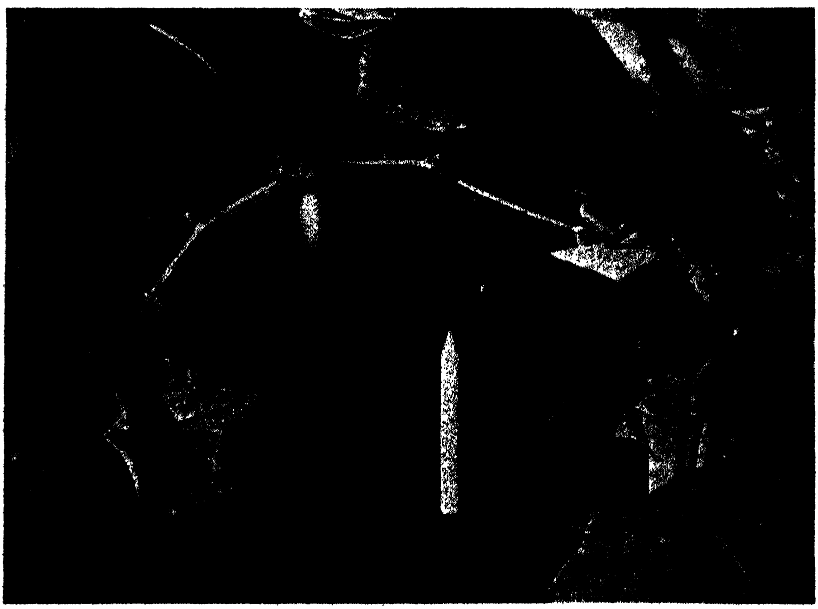

FIG. 1. Fruit of Mildew Resistant Cucumber being developed from cross of Puerto Rico 40 x Cubit.

was dusted with a copper fungicide, control of mildew was not adequate because of the irregular intervals of application necessitated by frequent and excessive rainfall. However, in spite of the early mildew infection, a good crop was harvested and the yields reported in Table I were as good as ever obtained from the fall crop.

TABLE I—YIELD OF COMMERCIAL CUCUMBER VARIETIES AND BREEDING LINES 1945 FALL CROP

Variety	Average Defoliation (Per Cent) (October 31, 1945)	Yield (Bushels Per Acre)	
		Fancy	Choice
Burpee Hybrid 170	55.0	205.0**	63.6
Marketer	80.0	150.2	61.0
Cubit	84.2	116.2	58.9
A & C	87.5	91.6	55.4
201A-4-4-1	32.5	230.0**	60.4
201-1-1A	29.2	201.0*	71.0
201-1-1-2	42.5	188.3*	80.0
201-1-1B	31.0	188.0*	75.0
34-8-1-1	47.5	178.0*	46.0
201-1-4-1	50.0	155.3	57.0
Difference required for significance at 5 per cent point		53.4	——

*Significantly greater than A & C or Cubit
**Significantly greater than A & C, Cubit, or Marketer

Marketer and Cubit produced fruits having the best type and color of any of the commercial varieties. A & C produced good fruits for only 7 to 10 days; after which the majority of the A & C cucumbers were short or misshapen. As shown in Table I, Burpee Hybrid 170 was the most productive commercial variety. It possesses some tolerance to mildew which undoubtedly prolonged its harvest season. This variety produces fruits that are green with a yellow mottling, a color which is only fair from the market standpoint. Fruit shape is somewhat tri-lobed but not undesirably so. Due to the high cost of producing the hybrid seed of this variety by hand pollination, its commercial planting is almost prohibitive.

The open-pollinated seed from the resistant breeding lines produced excellent crops as evidence by the outstanding yields reported in Table I. Some of the lines were segregating plants which produced too many short "pickle length" fruits which lowered the yield of market quality fruit. Except for this factor, the shape of the fruits was satisfactory and closely approached that of Cubit. Due to the high degree of segregation there was more variation in the shape and color of the fruits than in the commercial varieties. It was noteworthy that during the last half of the season the resistant lines produced fewer misshapen fruits than the commercial varieties. This was no doubt due to the premature defoliation of the latter as a result of mildew infection. The average estimated percentage of defoliation reported in Table I gives an indication of the importance of this factor. These figures are in general agreement with readings made on the spring crop when Cubit, Marketer, and A & C showed about 90 per cent defoliation as compared with 50 per cent for Burpee Hybrid and 10 per cent for the resistant lines. The major wave of infection of the resistant lines with mildew occurred during the rainy, windy period that accompanied the hurri-

cane of September 17. The foliage of all plants was injured by the wind and rain of that period. It is possible that the injury, especially the water soaking of the dorsal side of the leaves, was conducive to infection of even "resistant" foliage.

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Relation of Maturity to Yield and Quality of Raw and Canned Peas, Corn and Lima Beans[1]

By Amihud Kramer, *University of Maryland College Park, Md.*

Investigations on yield of vegetable crops are frequently carried out without reference to the stage of maturation of the product. The following data are presented to illustrate the vast differences in yield and quality that may be due entirely to differences in the stage of development of the vegetable crop at the time of harvest.

Materials and Methods

One acre of sweet (Pride) peas, one acre of Alaska peas; one-quarter acre each of Golden Cross Bantam, Aristogold, Country Gentleman, and Narrowgrain Evergreen corn; and one acre of Clark's Bush (green cotyledons, Henderson type) lima beans were grown at the plant research farm of the University of Maryland during the 1945 growing season. It was planned to harvest each variety five successive times at 2 to 5-day intervals so that the first harvest would yield material somewhat too young for optimum canning quality, the second harvest to coincide with the optimum stage that would make a very young (fancy) canned product; the third harvest was to provide young (extra standard) material; the fourth, nearly mature (standard); and the last harvest, low standard or substandard quality in reference to maturity.

The peas and beans, after harvesting, were threshed in a commercial viner, cleaned in a clipper mill, and brought in lug boxes to the laboratory where they were separated into sieve sizes, and washed in a riffle washer. Each batch, comprising one size, was then thoroughly mixed, portions were removed for tenderometer determinations, and the remainder were blanched for 3 minutes in water at 205 degrees F and filled into No. 1 cans. Hot brine composed of 2 per cent salt and 3 per cent sugar was added to the peas. The sugar was omitted from the brine for lima beans. The cans were then closed. The peas were processed for 35 minutes at 240 degrees F and the lima beans for 25 minutes at 245 degrees F.

The corn varieties were harvested by hand and immediately brought to the laboratory where they were husked by machine and cut by a commercial whole-grain cutter. After portions were removed for moisture and succulometer determinations, the cut kernels were washed in pans until the water was almost free of corn milk, filled into No. 2 cans, hot brine containing 2 per cent salt and 3 per cent sugar was added, and the cans were closed and processed for 50 minutes at 240 degrees F.

Tenderometer:—Readings in pounds of shearing force were obtained for raw washed peas by using a mechanical tenderometer. A revised hydraulic model was made available at the end of the season too late to obtain a complete set of data for the lima beans.

[1]Scientific Paper No. A125, Contribution No. 2013 of the Maryland Agricultural Experiment Station (Department of Horticulture).

Succulometer:—Readings in terms of milliliters of juice extracted from 100 grams of corn, both raw and canned, were obtained by using the succulometer, an instrument developed for this specific purpose. The instrument and directions for its use are described elsewhere (3).

Alcohol Insoluble Solids:—Determinations of the canned products were made as follows: 100 grams of the drained canned product were blended with 100 grams of water in a Waring Blendor, and 20 grams of the blended material were transferred with a few milliliters of water to a 400 ml. beaker, 150 ml. of 95 per cent ethyl alcohol were added, the beakers were covered and brought to a boil. The rest of the procedure was identical to the official method (1).

Ascorbic Acid:—The method used was identical to that described by King (2).

Results

The data on Alaska and sweet peas (Tables I and II) demonstrate again the close relationship between tenderometer readings on the raw

TABLE I—Relation of Maturity to Yield and Canned and Raw Alaska Peas

Days From Planting	Yield (Pounds/Acre)	Per Cent of Total	Tenderometer (Raw Peas)	A.I.S. (Per Cent) (Canned Peas)	Maturity Rating
			Sieve Size 1		
71	48	10.7	78	8.5	Very young
73	76	9.9	78	8.5	Very young
75	56	5.2	75	—	Very young
77	124	8.3	85	10.3	Very young
79	21	1.5	85	—	Very young
			Sieve Size 2		
71	129	28.7	82	10.3	Very young
73	229	30.0	84	10.3	Very young
75	376	34.8	86	11.0	Very young
77	312	20.8	97	12.8	Young
79	221	16.0	100	13.4	Young
			Sieve Size 3		
71	229	50.7	101	13.2	Very young
73	359	47.0	108	14.4	Very young
75	389	36.0	116	15.9	Young
77	599	39.9	133	17.9	Young
79	675	48.9	138	17.7	Young
			Sieve Size 4		
71	40	8.9	129	18.1	Young
73	95	12.4	140	19.0	Young
75	242	22.4	157	20.3	Nearly mature
77	438	29.2	171	21.1	Nearly mature
79	432	31.3	182	21.2	Nearly mature
			Sieve Size 5		
71	5	1.0	143	18.9*	Young
73	6	0.7	165	21.2*	Nearly mature
75	16	1.5	175	22.1*	Nearly mature
77	27	1.8	198	23.8*	Mature
79	32	2.3	220	24.8*	Mature
			Field Totals (Calculated)		
71	451	100.0	96	12.3	Very young
73	763	100.0	102	13.1	Very young
75	1,080	100.0	115	15.1	Very young to young
77	1,500	100.0	134	17.1	Young
79	1,380	100.0	147	18.1	Nearly mature

*Estimated from tenderometer values.

TABLE II—RELATION OF MATURITY TO YIELD AND QUALITY OF CANNED AND RAW SWEET (PRIDE) PEAS

Date Harvested	Yield (Pounds/Acre)	Per Cent of Total	Tenderometer (Raw Peas)	A.I.S. (Per Cent) (Canned Peas)	Maturity Rating
			Sieve Size 1 and 2		
85	317	28.8	74	7.2	Very young
89	361	19.5	80	8.0	Very young
92	40	1.6	—	—	—
95	41	1.6	—	—	—
			Sieve Size 3		
85	204	18.5	80	7.8	Very young
89	178	9.6	79	9.1	Very young
92	200	8.0	93	10.6	Young
95	95	3.7	144	16.7	Nearly mature
			Sieve Size 4		
85	362	32.9	85	8.4	Very young
89	744	40.2	93	10.2	Very young
92	715	28.6	102	11.8	Young
95	405	15.8	156	18.7	Nearly mature
			Sieve Size 5		
85	188	17.1	94	9.5	Very young
89	381	20.6	106	12.3	Very young
92	1,003	40.1	121	13.9	Young
95	1,450	56.5	160	18.6	Nearly mature
			Sieve Size 6+		
85	30	2.7	101	11.0	Very young
89	187	10.1	122	14.2	Young
			Sieve Size 6		
92	520	20.8	149	16.7	Nearly mature
95	541	21.1	187	20.8	Nearly mature to mature
			Sieve Size 7		
92	23	0.9	—	—	—
95	74	2.9	188	21.1	Mature
			Field Totals (Calculated)		
85	1,100	100.0	83	8.2	Very young
89	1,850	100.0	95	10.5	Very young
92	2,500	100.0	119	13.6	Young
95	2,566	100.0	165	19.1	Nearly mature

product and the alcohol insoluble solids per cent of the canned product (5). It is also apparent that the longer the harvest is delayed the smaller is the proportion of the total yield that can be expected to make very young (fancy) canned peas. When Alaska peas were allowed to grow until maximum yield was obtained, only about 8 per cent of the total yield made very young peas. Similarly, only about 2 per cent of the sweets made a very young canned product, when allowed to mature until maximum yield was reached. On the other hand, when the Alaska peas were harvested 2 days before maximum yield was obtained, 40 per cent of the peas resulted in a very young (fancy) canned product, but the yield was only 72 per cent of the maximum. Those peas that were harvested 4 days earlier produced 87 per cent fancy peas, but the yield was only about half of the maximum. For the sweet peas, advancing the date of harvest by 3 days resulted in 90 per cent fancy peas, but the total yield was only 74 per cent of the maximum.

The lima bean data show similar results, that is, the older the material, the higher the alcohol insoluble solids, and the lower the ascorbic acid content. Tenderometer readings on raw washed lima beans are incomplete because the new type tenderometer, capable of readings above 500 pounds (in contrast to the limit of about 220 pounds, for the standard machine), was not available until the end of the season. However, the meager data that are available indicate that tenderometer readings on raw lima beans and alcohol insoluble solids per cent of canned lima beans might be just as valuable in measuring objectively the maturity of lima beans as they have proved to be for maturity measurement of raw and canned peas respectively.

It is interesting to note that the smaller sizes of peas, though increasing gradually in maturity with every delay in harvesting are invariably more immature than the larger sizes for the same harvesting date. With lima beans, however, this is not the case, as is shown in the data in Table III. Apparently until September 21, maturity of the tiny size did average better than the larger sizes, but beyond that date, the smallest size rapidly became the poorest in respect to maturity. This may be explained very readily on the basis of changes in the

TABLE III—RELATION OF MATURITY TO YIELD AND QUALITY OF RAW AND CANNED LIMA BEANS (CLARK'S BUSH)

Code	Raw product					Canned product						
	Date of Harvest	Yield Pounds/Acre	Total Yield (Per Cent)	Tenderometer	Fill-in-Weight (Grams)	Size Grams/100 Beans	Drained Weight (Grams)	Increase Over Fill-in-Weight (Per Cent)	A.I.S.	Ascorbic Acid-Mg/100 Grams		
										Beans	Recovered From Liquor	Total
						Tiny						
703	Sep 14	298	23	—	210	44	224	6	17.7	7.8	6.2	14.0
722	Sep 19	197	10	—	190	47	5	5	17.7	8.0	7.8	15.8
741	Sep 21	257	14	—	180	64	198	10	20.9	4.8	5.5	10.3
761	Sep 26	481	26	304	150	76	185	23	27.5	1.2	1.9	3.1
792	Oct 1	865	62	510 +	120	80	160	33	26.8	0.8	1.5	2.3
						Small						
710	Sep 14	777	60	—	210	80	233	11	20.5	7.4	6.2	13.6
720	Sep 19	1,341	68	—	190	83	216	14	22.2	7.2	6.1	13.3
734	Sep 21	1,285	70	—	205	180	86	14	23.7	5.7	5.3	11.0
771	Sep 26	1,111	60	257	150	92	173	15	25.8	3.2	5.0	8.2
793	Oct 1	460	33	280	150	89	166	12	25.0	3.1	4.9	8.0
						Medium						
717	Sep 14	220	17	—	210	121	236	12	23.3	6.0	4.5	10.5
721	Sep 19	434	22	—	190	115	220	16	24.1	4.1	3.5	7.6
729	Sep 21	294	16	—	180	115	204	13	23.8	5.1	5.2	10.3
766	Sep 26	259	14	150	150	115	180	20	24.7	4.8	6.6	11.4
794	Oct 1	70	5	245	150	108	172	15	25.5	3.6	5.3	8.9
						Field Total (Calculated)						
	Sep 14	1,295	100	—	210	79	231	10	20.3	7.3	5.9	13.2
	Sep 19	1,972	100	—	190	86	215	13	22.2	6.6	5.7	12.3
	Sep 21	1,836	100	—	180	88	204	13	23.3	5.5	5.3	10.8
	Sep 26	1,852	100	266	150	91	177	18	26.1	2.9	4.4	7.3
	Oct 1	1,395	100	422	131	84	163	24	26.1	1.7	2.8	4.5

size of the individual lima beans. Lima beans of the Henderson type increase with maturity as they increase in size until they reach the "medium" size, at which time they are a little over one gram in weight. If they are allowed to remain in the field beyond the maximum size stage, they begin to shrivel, and if the harvest is delayed sufficiently long, they will shrivel back to the smallest "tiny" size. Thus, when the pods are just beginning to fill out, the smallest beans are the youngest, but if the vines remain in the field until a considerable proportion of the beans begin to shrivel, then the smallest size may be largely composed of these shriveled beans, and may consequently be the most mature. The maximum yield for lima beans was reached when some of the beans began to shrivel, as indicated by the small increase in per cent of tiny lima beans on September 21. Thus, even from the yield standpoint, it is unwise to delay harvest beyond that point.

Kramer and Mahoney (4) have shown that if the blanching is held constant, ascorbic acid is a good measure of quality. This is borne out by the ascorbic acid data in Table III.

The data on corn in Table IV show that the total yield of corn does not vary materially over a considerable period of time, but that the yield of cut kernels does increase with increasing maturity up to a certain point. Thus, just as with peas and lima beans, maximum yields of cut kernels do not coincide with optimum maturity. However, whereas maximum yields of Golden Cross Bantam and Country Gen-

TABLE IV—Relation of Maturity to Yield and Quality of Raw and Canned Whole Kernel Corn

Code	Date Harvested	Yield Pounds Per Acre			Raw Product		Canned Product	
		Total	Husked Ears	Cut Kernels	Moisture	Succulometer	A.I.S.	Succulometer
				Golden Cross Bantam				
304	Aug 11	7,060	3,601	1,786	76.4	25.0	15.2	23.0
308	Aug 13	7,392	4,066	2,144	75.6	25.0	17.1	22.4
316	Aug 16	7,341	4,478	2,202	69.7	21.4	20.8	20.4
328	Aug 20	7,710	4,857	2,544	65.1	18.4	22.5	16.6
341-2	Aug 23	7,245	4,990	2,463	62.2	12.6	25.7	14.0
				Aristogold				
314	Aug 14	5,678	3,180	1,478	77.0	23.8	16.2	21.9
322	Aug 17	6,490	4,024	1,687	72.6	22.8	18.3	20.4
336	Aug 21	7,455	4,771	2,013	68.0	20.6	22.5	16.8
345-6	Aug 24	7,055	5,221	2,258	65.7	19.6	24.6	14.8
359-60	Aug 28	7,759	5,819	2,948	62.9	15.7	26.0	12.0
				Narrowgrain Evergreen				
312	Aug 14	6,061	2,970	1,030	78.4	25.0	15.0	23.7
326	Aug 17	5,628	3,480	1,126	74.6	22.0	18.5	19.0
340	Aug 21	6,884	5,783	1,721	68.8	19.6	22.5	16.5
347	Aug 24	5,929	4,269	1,957	66.7	20.0	24.2	15.0
351-2	Aug 28	6,589	4,810	2,899	65.2	17.2	25.5	12.5
				Country Gentleman				
320	Aug 16	3,977	2,028	994	——	24.0	15.6	20.7
332	Aug 20	6,310	3,786	1,641	70.1	19.9	22.1	13.8
343	Aug 23	6,007	4,085	1,802	67.8	17.8	23.4	12.8
349	Aug 27	5,618	3,820	1,854	66.1	16.1	25.4	11.6
379-80	Aug 31	5,104	3,777	1,837	61.5	12.8	26.8	10.5

tleman are reached when the material may be expected to produce young (extra standard) quality, the maximum yields of cut kernels of Aristogold and Narrowgrain Evergreen are not reached until the material averages low standard in quality.

Discussion

Horticulturists have long recognized that differences in yield may be due to soil or climatic differences, or to chance variability alone. As a result of this realization, many horticultural data are now analyzed statistically in order that conclusions may be drawn with reasonable assurance that yield differences are not due to some uncontrolled factor, or to chance alone. Is it not time to make reasonable adjustments for maturity differences as well?

The data presented above demonstrate clearly that differences in yield arising from differences in maturity may be far greater than differences caused by soil heterogeneity or even varieties. However, reports on yields of vegetables as affected by such variables as varieties, fertilizers, spacing, rotation, etc., sometimes include no mention of the maturity of the various treatments, and rarely include adequate objective tests of maturity. Thus, for example, if the yields of the Alaska and sweet peas were compared (Tables I and II), and the sweet peas were harvested when the average tenderometer reading was 80, while the Alaska peas were harvested when the average tenderometer reading reached 130, it would appear that the Alaska peas outyielded the sweet peas, when actually the reverse was probably the case.

One date of harvest may not necessarily represent the true yield, even when extreme care is taken to harvest all treatments at an equivalent stage of maturity. For example, the investigator may wish to determine the comparative yields of several strains of sweet corn when used for whole kernel, and for cream style corn. If the varieties were harvested at optimum maturity for very young (fancy) whole kernel corn, the yield data would supply valid yield comparisons for the whole kernel pack; however, there is no assurance that the varieties would perform in the same relative manner if they were allowed to mature to the point where they would make relatively thick cream style corn. In fact, the data in Table IV indicate that when Golden Cross Bantam and Aristogold were harvested at a very young stage of maturity, the Bantam variety outyielded Aristogold by about 25 per cent, but when the two varieties were allowed to mature to the nearly mature (standard) stage, which would be used ordinarily for cream style corn, the Aristogold variety outyielded Golden Cross Bantam by about 20 per cent.

It is, therefore, suggested that whenever yield records are reported, particularly where varieties are compared, that the purposes for which the product is to be used be considered carefully, and perhaps three separate cuttings be obtained at different times, the first being preoptimum in maturity, the second as close as possible to the optimum, and the third past the optimum stage for each purpose. If for reasons of economy this cannot be done, then at least some reliable, objective

index of maturity should be reported together with the yield figure, so that some allowance may be made for possible differences in maturity.

SUMMARY

Data are presented to illustrate the fact that yields may be greatly affected by differences in maturity at time of harvest for such products as peas, lima beans, and sweet corn. It is recommended that yield data, for products that are harvested in an immature stage, be accompanied by a reliable index of maturity, such as tenderometer or alcohol insoluble solids for peas and lima beans, and moisture, alcohol insoluble solids, or succulometer for corn, in order that due allowance may be made for this variable in interpreting data.

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Effect of a Volatile from Honey Dew Melons on the Storage Behavior of Certain Vegetables[1]

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During the summer of 1945, a small constant temperature room (50 degrees F) was used concurrently for cucumber and melon storage tests. Results obtained in 1944 and experiments previously published (5, 8) indicated the desirability of 50 degrees as a holding temperature for cucumbers. However, in the 1945 tests the cucumbers became yellow and decayed much sooner than was to be expected. The most obvious variable was the presence of the Honey Dew and Cranshaw[2] melons in the room during the 1945 tests.

It was necessary to evaluate the effect of the melons in order to be able to interpret the results of the cucumber experiments that had been conducted in storage rooms containing Honey Dew and other melons.

Many fruits are known to release ethylene during ripening and ethylene is known to accelerate ripening and loss of chlorophyll. Smock (9) has reported that it is possible for one lot of apples to hasten the ripening of a second lot in storage. Denny and Miller (1) reported an epinastic response of potato plants to emanations of California-grown cantaloupes and concluded that this was indicative of ethylene production. It appeared logical to suspect that the increased deterioration of the cucumbers noted above was due to the production of ethylene or a similar material by the melons.

This paper reports the results of tests in which certain vegetables and etiolated pea seedlings were held in closed chambers with Honey Dew or other melons. These tests were preliminary in nature but substantiated the original supposition that Honey Dew melons produce a volatile capable of reducing the storage life of certain vegetables. This volatile produced effects on pea seedlings characteristic of ethylene. Only melons nearing a table-ripe stage produced these symptoms on pea seedlings.

Experimental

The general procedure was to hold certain vegetables with Honey Dew or other melons in closed chambers and then compare them with similar lots held in chambers without melons or in the air of the room. Temperatures of 32, 50, and 70 degrees F were utilized but all lots were held in the open air of a 70 degree room after their removal from the closed chambers. All vegetables were freshly harvested for these tests except some cucumbers as noted below. Steel drums of 35-gallon capacity and trash cans of about 25-gallon capacity were used as storage chambers within the constant temperature rooms. The lids of these containers fit snugly but were not air-tight. No attempt was

[1]Supported in part by grants from the Refrigeration Research Foundation and the California Association of Ice Industries.

[2]New high quality California melon of obscure origin. Both Crenshaw and Cranshaw are commonly used names.

made to control the concentration of carbon dioxide or oxygen within the chambers.

It has been shown by Knight, *et al.* (4), Knight and Crocker (3) and Harvey (2) that etiolated pea seedlings show characteristic symptoms when exposed to dilute concentrations of ethylene. The internodes cease to elongate, the stems become enlarged and the plant bends from a vertical position and grows horizontally. This response has been referred to as the "triple response". Recently Rohrbaugh (6) has used this response as a test for ethylene in commercial lemon storages.

Etiolated pea seedlings of the Alaska variety were used as test material in the present study. Fifteen to 25 seedlings were germinated in small cans in the dark at 80 degrees until 4 to 6 cm in height. They were then transferred to the chamber to be tested and held there for 3 or 4 days. All tests with pea seedlings were conducted at 70 degrees.

Tests with Cucumbers:—Four tests were conducted in which cucumbers of slicing maturity were held with melons and compared with similar lots held without melons. The duration and temperature of the exposure to melons is indicated in Table I. Each lot contained 10 to 12 cucumbers. These were of the Cubit variety, grown at Davis, except for Test 3. The cucumbers used for Test 3 were purchased on the Sacramento market and had been held in storage at 45 to 50

TABLE I—EFFECT OF HOLDING CUCUMBERS IN CLOSED CHAMBERS WITH MELONS ON THE KEEPING QUALITY OF THE CUCUMBERS

Storage Temperature (Degrees F)	Variety of Melon in Closed Chamber	Days in Closed Chamber*	Condition of Cucumbers When Removed from Closed Chamber	Days to Become Unusable at 70 Degrees F
	Test 1			
70	Honey Dew (G-R)**	8	Poor	2
	None	8	Fair to good	25
	Test 2			
50	Honey Dew (R)†	8	Good	3
	None	8	Good	14
	Honey Dew (R)	16	Very poor	1
	None	16	Fair to good	6
	Test 3			
50	Honey Dew (G-R)	8	Poor	1
	None	8	Poor to fair	7
	None††	8	Poor	4
	Test 3			
32	Cranshaw (G-R)	8	Fair to good	2
	Honey Dew (G-R)	8	Fair to good	2
	None	8	Fair to good	2
	None††	8	Poor	2
	Test 4			
32	Cranshaw (R)	8	Excellent	4
	Honey Dew (R)	8	Excellent	4
	None	8	Excellent	4
	None††	8	Good	3

*Cucumbers removed to open air of 70 degrees F room after indicated storage with melons.
**G-R = Green to ripe.
†R = Ripe.
††Cucumbers held in open room, not in closed chamber.

degrees F for 8 days. The variety was unknown but was of a long green slicing type. Only Honey Dew melons were used in the tests at 50 and 70 degrees but Cranshaw melons were included in the tests at 32 degrees. The maturity of the melons is indicated in Table I. From five to eight melons were used per drum.

Cucumbers held in a closed chamber with Honey Dew melons at 50 and 70 degrees for 8 days deteriorated rapidly when removed to the open air of the 70 degrees room. The melons increased yellowing and decay of the cucumbers (Fig. 1). Thus, the original supposition that melons emit an active volatile that could impair the keeping quality of cucumbers was substantiated.

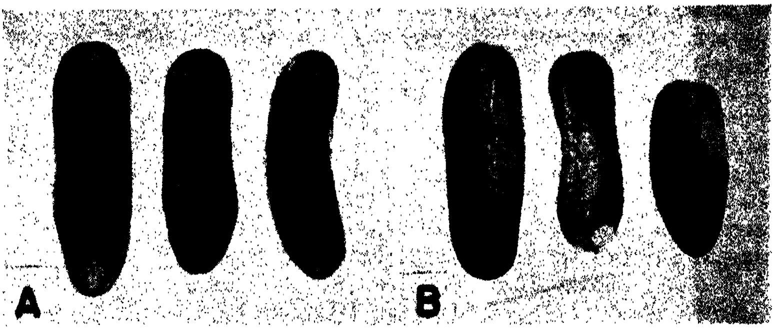

FIG. 1. Result of holding Cubit cucumbers with Honey Dew melons for 8 days at 70 degrees F in a closed chamber. A. Control. B. With melons. Picture taken 8 days after removal from closed chambers. Best, average, and poorest fruits arranged left to right for each lot. Note the lighter color and more decay in B as compared to A.

The control lot at 70 degrees required an exceptionally long period before it was classed as unusable. The limited comparisons possible in Table I should not be construed to indicate that cucumbers held continuously at 70 degrees have a longer storage life than those held at 50 degrees for a period prior to transfer to 70 degrees. Only in the case of Test 3 are results at different temperatures strictly comparable. Holding in a closed chamber without melons at 50 degrees gave somewhat better results than holding in the open room. This might have been attributable to a more favorable gas concentration.

There was no visible effect of either Honey Dew or Cranshaw melons on cucumbers at 32 degrees. Since cucumbers are very susceptible to chilling injury (5), the rapid deterioration of the controls tended to erase any effect that the melons might have had. It is concluded that if cucumbers are held as long as 8 days at 32 degrees the presence of melons in the storage room will have little or no effect.

Tests with Other Vegetables:—Mature green tomatoes (Variety 133–6) held in a closed chamber with Honey Dew melons for 8 days at 70 degrees ripened more slowly and with more decay than fruits held without melons. This is at variance with the response of cucumbers and was not expected since Rosa (7) and others have found that

ethylene will hasten the ripening of tomatoes. Possibly, a high concentration or a long exposure can inhibit ripening. An alternate explanation exists; the melons might have changed the oxygen or carbon dioxide concentration sufficiently that normal tomato ripening did not occur. At 50 degrees the effect of the Honey Dew melons on tomato ripening was slight.

A test with summer squash at 70 degrees using Black Zucchini and Early Prolific Straightneck squash indicated little or no effect of Honey Dew melons on the Black Zucchini. The Early Prolific Straightneck were soft and spongy when removed from the melon chamber compared to a firm condition of the control held without melons. Two tests in which No. 45 Powdery Mildew Resistant cantaloupes were held with Honey Dews at 70 degrees indicated no effect on the No. 45's attributable to the Honey Dews. However, none of the lots ripened properly due to the lateness of the season — late October.

These results with summer squash and No. 45 cantaloupes are not conclusive but tend to indicate that the effect of the melons was not especially marked.

Tests with Pea Seedlings:—The results of holding Alaska pea seedlings with various varieties of melons and with cucumbers at 70 degrees are summarized in Table II. In Test 1, peas held with cu-

TABLE II—Effect of Holding Alaska Pea Seedlings in Closed Chambers with Melons and Cucumbers on the Growth of the Peas at 70 Degrees F

Lot Number	Vegetable in Closed Chamber	Days in Closed Chamber	Initial Plant Height (Cm)	Final Plant Height (Cm)	Bending of Stems
	Test 1				
302	None	4	4	18.5	None
303	12 cucumbers, green	4	4	9.5	Very slight
304	5 Honey Dew melons, green to ripe	4	4	6.5	Definite
305	4 Cranshaw melons, green to ripe	4	4	9.5	Very slight
	Test 2				
323	None	3	6	16.5	None
324	12 cucumbers, slight yellowing	3	6	12.0	None
325	5 Honey Dew melons, green to ripe	3	6	9.0	Definite
326	5 Cranshaw melons, green to ripe	3	6	8.0	None*
327	4 Casaba melons, ripe	3	6	12.0	None
	Test 3				
328	8 Honey Dew melons, green	4	6	20.0	None
329	5 Honey Dew melons, shipping ripe	4	6	21.0	None
330	8 Honey Dew melons, table ripe	4	6	8.0	Definite
331	None	4	6	23.0	None
334	None (peas in open room)	4	6	20.0	None

*Stems dead at tip.

cumbers, Cranshaw melons and Honey Dew melons were definitely stunted. The plants with Honey Dews showed an enlargement of the stems and a definite horizontal bending. Slight bending occurred on those plants with cucumbers and Cranshaws (Fig. 2).

In Test 2, cucumbers and Casaba melons resulted in a slight stunt-

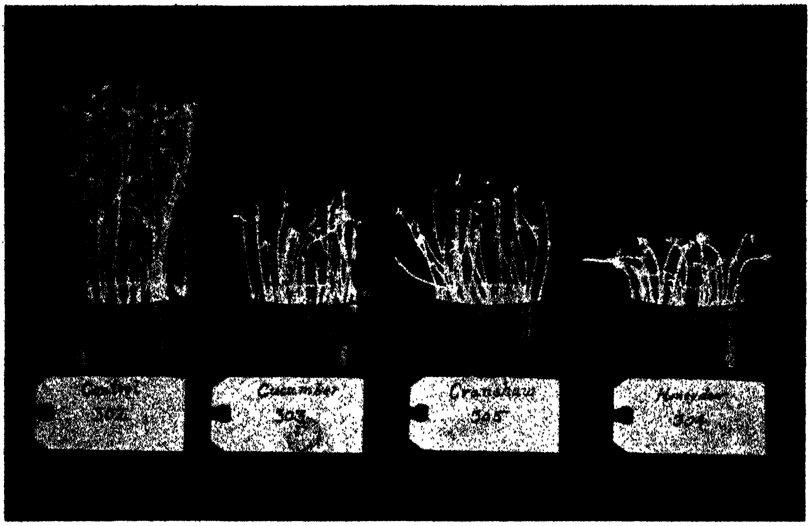

Fig. 2. Pea seedlings after holding in closed chamber with indicated vegetable for 3 days at 70 degrees F.

ing whereas Honey Dew and Cranshaw melons caused a severe stunting of pea seedlings. Horizontal bending occurred only on those held with the Honey Dew melons.

Test 3 was set up to determine the effect of maturity of Honey Dews. The melons were sorted into three stages of maturity: definitely green; intermediate — shipping ripe; and definitely ripe. It was found that only the ripe Honey Dews caused a noticeable effect on the peas (Fig. 3). A number of workers have concluded that ethylene production is associated with ripening.

These tests show that at 70 degrees Honey Dew melons emit a volatile capable of producing the "triple response" characteristic of ethylene on etiolated pea seedlings. Only Honey Dews in a table ripe condition are active in this regard. The stunting and slight bending of the plants with cucumbers indicate that they may give off lesser amounts of this volatile.

Discussion

The results observed here indicate that Honey Dew melons, and possibly other varieties as well, can emit sufficient quantities of ethylene (or similarly acting substance) to reduce the storage life of cucumbers and possibly certain other vegetables. Further tests are needed to evaluate this effect under commercial conditions. The practice of holding vegetables in small experimental rooms containing ripe melons is definitely untenable.

Honey Dew melons are often held in a confined space with other varieties of melons and with other fruits and vegetables. Mixed cars and warehouse storage are common examples.

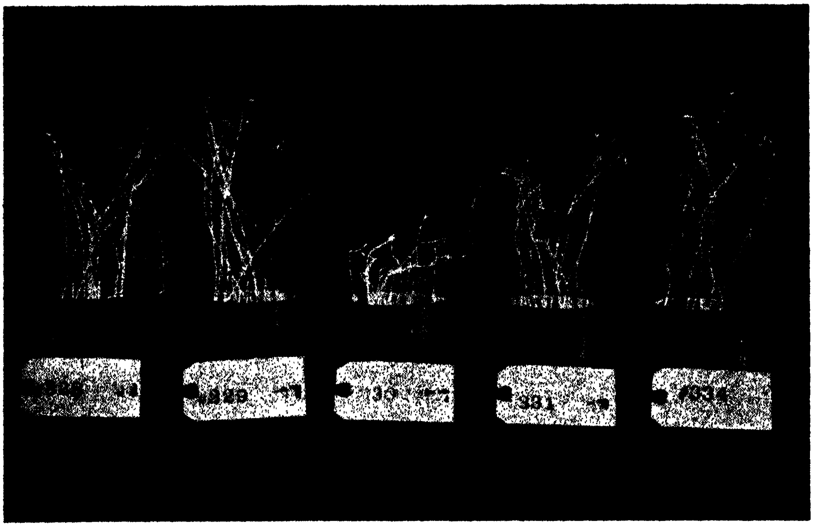

FIG. 3. Pea seedlings after 4 days at 70 degrees F; No. 328 with green Honey Dew melons; No. 329 with Honey Dews of shipping maturity; No. 330 with table ripe Honey Dews; No. 331 Control, closed chamber; No. 334 Control, open to room.

At the beginning of the season, shippers sometimes treat Honey Dews and other melons with ethylene to hasten coloring, after loading. Perhaps the addition of a few ripe Honey Dews before shipment might give the same result.

Some attempt has been made to determine the experiences of shippers who load mixed cars of vegetables containing Honey Dew melons. The observations to date indicate that such cars frequently show poor arrivals but the effect has not been attributed by these shippers to the presence of the Honey Dews.

SUMMARY

Honey Dew melons produce an emanation that is capable of reducing the storage life of cucumbers held in close proximity. This volatile material produces the "triple response" on etiolated pea seedlings characteristic of ethylene. Only table-ripe Honey Dews are effective in producing this material. There is some indication that cucumbers and Cranshaw melons produce small amounts of this volatile.

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Inheritance of Male Sterility in Winter Squash

By D. H. SCOTT and MARY E. RINER, *U. S. Department of Agriculture, Cheyenne, Wyo.*

IN THE squash breeding work at the Cheyenne Horticultural Field Station one of the objectives is to develop an early, high-quality, bush type of *Cucurbita maxima* Duch. As a feature of the work it has been necessary to have a self-pollinated fruit on each plant within each line, since most of the lines are segregating for a number of characters and selections cannot be made until late in the season. During the pollination work in the summer of 1944 several plants were found with male flowers which produced no pollen. The male-sterile flower character and its inheritance are presented in this report.

The male-sterile plants were discovered in seven different lines all of which involved Golden Hubbard and Tapley[1] parentage. Three of the lines were (Golden Hubbard x Tapley) x Golden Hubbard inbred 4 generations, two were (Golden Hubbard x Tapley F_2) x Golden Hubbard inbred 3 generations, and one was [(Golden Hubbard x Tapley) x (Buttercup x Tapley)] x [(Golden Hubbard x Tapley) F_2] inbred 3 generations. The Buttercup, Golden Hubbard, and Tapley varieties had all been inbred three generations before being used as parents.

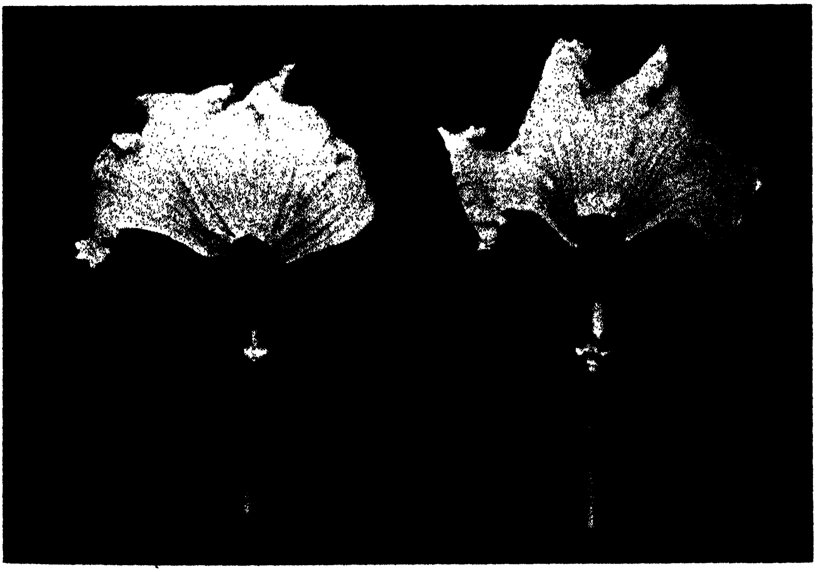

FIG. 1. Winter squash male blossoms: male-sterile flower on left and male-fertile on right.

[1]Tapley is a local name designating a squash line obtained in 1937 from W. T. Tapley of the New York State Agricultural Experiment Station at Geneva.

Hutchins (1) noted a variant that was both male and female sterile in which the male-sterile flower was much smaller than a normal flower. Apparently his is a different factor from the one reported here. With the Cheyenne material, the male-sterile plants when sibbed to male-fertile plants within each respective line set fruit readily and produced an abundance of seed. There is little or no difference in the size and shape of the male-sterile versus the normal flower, but there is a marked difference in the appearance of the androecium of the two types of male flowers (Fig. 1). In the male-sterile flowers the androecium apparently aborts in the bud stage before the staminate flowers open so that no pollen is produced. This corresponds closely to the condition noted by Shifriss (2) in *Cucurbita pepo* L.

The factor for male sterility (ms) is inherited as a simple recessive, as is shown by the data in Table I. Some of the male-sterile plants that

TABLE I—Progenies of Winter Squash Segregating for Male-sterile vs. Male-fertile Flowers

Line	Genotype	Observed		Expected		X^2
		Male-sterile	Male-fertile	Male-sterile	Male-fertile	
132-8×132-5	ms×(ms×MS)	20	19	19.5	19.5	0.03*
160-6×160-8	ms×(ms×MS)	171	183	177	177	0.41*
160-23×160-25	ms×(ms×MS)	13	12	12.5	12.5	0.04*
G-170	ms×(ms×MS)	73	90	81.5	81.5	1.77*
G-171	ms×(ms×MS)	44	45	44.5	44.5	0.01*
G-181	ms×(ms×MS)	28	32	30	30	0.27*
G-182	ms×(ms×MS)	43	44	43.5	43.5	0.01*
132-5 Selfed	msMS Selfed	75	210	71.25	213.75	0.26*
147-10 Selfed	msMS Selfed	27	79	26.5	79.5	0.01*
160-8 Selfed	msMS Selfed	26	70	24	72	0.22*

*No significant difference between the "observed" and "expected".

bore sibbed fruits were asexually propagated and moved into the greenhouse where they were backcrossed to plants grown from the sibbed seed. In the backcross progenies a 1 : 1 segregation for male-sterile versus male-fertile was observed. In the F_2 progenies a 3 : 1 segregation occurred.

The male sterility character may be of practical value for seed production if hybrid vigor should occur in certain crosses, as seems likely. In this connection it is interesting to point out that the male-fertile plants tend to blossom a few days earlier than the male-steriles. Table II gives the blossom dates for some of the segregating populations and it can be seen that many of the male-fertile plants could be eliminated 3 to 4 days before the male-sterile plants (which would be used to produce the hybrid seed) blossomed. Within 4 to 5 days from the time the first plants had blossomed most of the male-fertile plants had borne a flower, but it was 8 or 10 days after first bloom before the male-sterile plants had blossomed.

In winter squash, *Cucurbita maxima*, the plants are monoecious, the staminate and pistillate flowers being borne separately on the plant. A character for male sterility was observed which is inherited as a simple recessive to the male-fertile type or is conditioned by a single factor difference.

TABLE II—RELATIVE TIME OF BLOOM OF SQUASH PROGENIES SEGREGATING FOR MALE-STERILE VS. MALE-FERTILE FLOWERS

Line	Genotype	Plant Type	Number of Plants Blossomed by Specific Dates				Total
			Aug 7	Aug 11	Aug 15	Aug 18	
G-181	ms×(ms×MS)	Male-sterile	4	1	15	8	28
		Male-fertile	26	6	0	0	32
G-182-a	ms×(ms×MS)	Male-sterile	0	0	5	6	11
		Male-fertile	5	6	0	0	11
			Sept 1	Sept 5	Sept 8	Sept 14	
G-182-b	ms×(ms×MS)	Male-sterile	9	4	15	13	32
		Male-fertile	17	16	0	0	33
160-6×160-8	ms×(ms×MS)	Male-sterile	1	26	38	61	126
		Male-fertile	100	30	1	1	132
			Oct 11	Oct 15	Oct 17	Oct 19	
132-5	msMS selfed	Male-sterile	1	11	25	38	75
		Male-fertile	29	140	40	1	210
147-10	msMS selfed	Male-sterile	0	2	8	17	27
		Male-fertile	25	39	15	0	79
160-8	msMS selfed	Male-sterile	2	5	7	4	18
		Male-fertile	36	19	0	0	55

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California Sweet-Corn Suckering Studies

By John H. MacGillivray, P. A. Minges, Bernarr J. Hall, Hilton B. Richardson, and D. N. Wright,[1]
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Pruning of the corn plant has been customary for a good many years. When the secondary or side stems (shoots) of sweet corn or field corn are removed at the base, the practice is known as "suckering". For field corn only there has been developed in some states, a practice of removing the portion of stalk above the mature ear. This has been called "topping." Both suckering and topping are pruning operations and therefore may reduce growth and leaf area, thus lessening the manufacture of carbohydrates. The number of ears is reduced somewhat through the removal of suckers.

Suckering of sweet corn has been practiced throughout California except in a recently developed area in the Delta of the Sacramento and San Joaquin rivers. The benefits claimed are as follows: (a) a larger yield, (b) a larger yield of marketable corn, (c) increased earliness, and (d) larger individual ears. Obviously, the practice is not justified unless it improves production sufficiently to pay a profit above the cost of the operation. Since suckering has been so common in the past, one would expect the yields to be significantly greater and the increased production to compensate the grower for the labor involved. The tests here reported have been conducted for several years, both at Davis and in various important sweet-corn producing counties through the cooperation of the Farm Advisors (County Agents).

Labor Required and Cost of Suckering

Cost-accounting studies were conducted in 1941 in two important sweet-corn producing counties, namely Alameda (3) and Los Angeles (1). In both areas the growers' corn was suckered an average of 2.2 times. In Alameda County this operation required an average of 32 manhours per acre; it cost $13.18, or 11 per cent of the total costs, and was more expensive than any other item except fertilizer. In Los Angeles County, suckering required 36½ manhours per acre; it cost $12.89, or 10 per cent of the total costs, and was more expensive than any other material or operation.

Sometimes the suckers from sweet corn are used for livestock feed. This practice may be justified under conditions of extreme feed shortage but, even then, is probably uneconomical.

Trials in Other States

Suckering experiments have been conducted in three states on field corn and in three states and Canada on sweet corn. McCrory (2) has reported on this practice with reference to sweet corn grown under conditions of heat and drought and also gives a summary of other corn

[1]Bernarr J. Hall, Hilton B. Richardson, and D. N. Wright are Assistant Farm Advisors in San Diego, Riverside, and Fresno counties respectively.

suckering tests. Though these experiments were all conducted east of the Rocky Mountains, they clearly indicate that this practice does not increase yield and in some cases may even be detrimental. These previous studies have been instrumental in causing eastern growers to abandon sweet-corn suckering as an essential operation.

Physiology of the Problem

Suckering is a pruning operation that reduces the size and leaf area of the plant. In the test conducted in San Diego County in 1942, the number of leaves per plant for each treatment was recorded at the time of harvest. The averages were 25 leaves per plant when nonsuckered; 21 leaves when suckered once early; 12 leaves when suckered twice; and 11 leaves when given a single late treatment. The popular opinion is that this reduction of plant size will lower the water and nutrient requirements of the plant, thus encouraging larger individual ear growth. On the other hand, the pruning reduces the leaf area available for manufacturing sugars or carbohydrates, which make up the organic material found in the sweet-corn ear. A larger supply of carbohydrates should increase root growth so that nutrients and water may be obtained from a larger volume of soil. The response to pruning is not always uniform with different crops, soil, or climatic conditions. Further study is being made of the relation of irrigation and spacing to the effect of suckering on yield. The pruning of greenhouse tomatoes or sweet potato vines has caused reduced yields, as have also extended harvestings of asparagus.

Sweet corn is often grown by persons familiar with the production of tree fruits. Since pruning is extremely important for orchards, its effects on tree fruits should be compared with its effects on sweet corn.

The pruning of tree fruits is considered essential, but the method and severity vary with different species and also with different soil and climatic areas. Of the five reasons enumerated by Tufts (4) for pruning trees, only the objective of securing good size and quality of fruit would apply to sweet-corn suckering. Practically all pruning of mature trees is performed in the dormant season — a schedule that will not apply to an annual plant. Summer pruning is not recommended on mature fruiting trees because it will cause the production of smaller fruits. Summer pruning of young trees "at any time is devitalizing, and midsummer cutting is more weakening than cutting done early in the season." Thus it would seem that summer pruning (suckering) of sweet corn and deciduous trees must have similar effects, namely possible reduced yield and size of fruit.

Methods

The plots, each consisting of two rows, ranged in length from the minimum of 25 feet to a maximum of 180. They were replicated as shown in Table I. The treatments were as follows: (a) not suckered, (b) suckered early once when the stalk was 12 to 18 inches high, (c) suckered early and the suckering repeated once or twice, and (d) suckered late once when plants began to tassel. All trials were conducted on irrigated plots.

Description of Experimental Areas

Davis (Experiments 1, 2, 3, 7, and 8):—The crops were grown on the University Farm and were planted in early spring. The rows were 3 feet apart, with plants 16 to 18 inches apart in the row.

Los Angeles County (Experiments 4, 5, and 6):—Tests 4 and 5 were made at the County Farm under the direction of A. F. Gillette, formerly Assistant Farm Advisor, and Mr. Iberg, Farm Superintendent. There was some pilferage and wireworm damage on the Oregon Evergreen test plot (Experiment 5). Plot 6 was located on the ranch of J. W. Spencer near Artesia.

San Diego County, (Experiments 9, and 13):—Test 9 was made in Mission Valley on the C. S. Bond ranch. Test 13 was at El Cajon on the L. H. Saunders ranch. Both tests were conducted by B. J. Hall.

Riverside County, Coachella Valley (Experiment 10):—This experiment was on the Whittier Ranch near Indio, with Robert Bowlin as the cooperator and H. B. Richardson supervising the test.

San Joaquin County (Experiment 11):—This test was made in a field of corn grown near Terminous, for the San Francisco market, on the Richmond Chase ranch.

Fresno County (Experiment 12):—The test was conducted on the ranch of Roy Phillips near Sanger, under the supervision of D. N. Wright.

San Bernardino County (Experiment 14):—This test, made on the ranch of Charles Pierce near Chino, was conducted by Paul Moore, formerly Assistant Farm Advisor.

Results and Discussion

Tables I to IV give the data collected in seven different areas of the state over a period of 4 years. In these 14 tests there was not a single case where suckering gave significantly better production.

TABLE I—Yields of Sweet Corn from Suckering Treatments Expressed in Pounds of Marketable Ears Per Plant

Experiment Number	Year	Location (Nearest City)	Variety*	Harvest Period	Number of Replications	Yields in Pounds Per Plant: No Suckering	Early Suckering	Weekly Suckering	Late Suckering	Significance**
1	1940	Davis	G. B.	7/17–8/2	4	0.65	0.45	0.39	0.36	N. S.†
2	1941	Davis	G. C. B.	7/25–8/7	4	1.38	1.50	1.32	1.16	N. S.
3	1941	Davis	O. E.	8/5–8/11	4	1.06	1.18	1.07	1.05	N. S.
4	1941	Los Angeles	G. C. B.	7/21	4	0.86	0.76	0.74	0.60	0.05
5	1941	Los Angeles	O. E.	8/1	4	0.36	0.47	0.50	0.43	N. S.
6	1941	Los Angeles	O. E.	8/3–8/8	4	1.20	—	1.03	—	N. S.
7	1942	Davis	G. C. B.	7/17–7/29	4	0.80	0.94	0.80	0.84	N. S.
8	1942	Davis	O. E.	7/28–8/3	4	0.80	0.97	0.96	1.02	N. S.
9	1942	San Diego	G. C. B.	8/10–8/18	4	0.81	0.85	0.75	0.88	N. S.
10	1942	Indio	G. C. B.	6/1	4	0.98	0.98	0.92	0.90	N. S.
11	1942	Terminous	G. C. B.	8/27–9/8	4	1.28	1.10	1.04	0.97	0.14
12	1943	Fresno	G. C. B.	9/6	4	0.93	0.90	0.80	—	N. S.
13	1943	San Diego	G. C. B.	—	4	0.72	0.72	0.70	0.64	N. S.
14	1943	Chino	G. C. B.	7/26–7/29	3	0.84	0.81	0.70	—	N. S.

*G. B. = Golden Bantam; G. C. B. = Golden Cross Bantam; O. E. = Oregon Evergreen.
**Least significant difference for odds of 19 to 1.
†N. S. = Not significant.

With regard to pounds of unhusked ears produced per plant (Table I), in eight of the tests the greatest yield was obtained on the nonsuckered plants. Two of these yields were significantly greater. In all cases except three, the late suckering produced the lowest yields. Table II shows two cases where the number of ears per stalk was significantly increased by the nonsuckering treatment. In the remaining tests the differences were not significant, but in eight of these the nonsuckered plants showed the best average yields. Suckering did not significantly affect the ear sizes, as is shown by Table III. It did result in a decreased size of plant (Table IV), and usually this reduction was proportional to the severity of pruning.

In these tests suckering failed to hasten maturity; in 10 out of 11 trials there was no significant increase in early yields from the suckered plots. In the Oregon Evergreen experiment at Davis in 1941, significantly higher early yields were obtained from the early and repeated

TABLE II—YIELDS OF SUCKERING TREATMENTS EXPRESSED IN THE NUMBER OF EARS PER PLANT AND DOZENS OF SWEET CORN PER ACRE

Experiment Number	Year	Location, (Nearest City)	Marketable Ears (Number Per Plant)					Marketable Ears (Dozens Per Acre)			
			No Suckering	Early Suckering	Weekly Suckering	Late Suckering	Significance	No Suckering	Early Suckering	Weekly Suckering	Late Suckering
1	1940	Davis	1.88	1.48	1.08	1.01	N. S.	1,175	925	675	631
2	1941	Davis	2.14	2.43	2.07	1.78	N. S.	1,552	1,755	1,501	1,291
3	1941	Davis	1.36	1.49	1.38	1.31	N. S.	986	1,080	1,001	950
4	1941	Los Angeles	1.28	1.10	1.04	0.92	N. S.	1,280	1,100	1,040	920
5	1941	Los Angeles	0.48	0.69	0.67	0.57	N. S.	360	518	503	428
6	1941	Los Angeles	1.29	—	1.09	—	N. S.	1,076	—	909	—
7	1942	Davis	1.54	1.68	1.43	1.40	N. S.	1,194	1,302	1,108	1,085
8	1942	Davis	1.16	1.34	1.37	1.47	N. S.	928	1,072	1,096	1,176
9	1942	San Diego	1.44	1.48	1.23	1.54	N. S.	1,410	1,413	1,190	1,386
10	1942	Indio	1.73	1.69	1.65	1.67	N. S.	1,677	1,646	1,537	1,592
11	1942	Terminous	1.94	1.75	1.70	1.53	0.25	1,594	1,438	1,397	1,257
12	1943	Fresno	1.49	1.46	1.30	—	N. S.	1,458	1,500	1,313	—
13	1943	San Diego	1.20	1.16	1.10	1.10	N. S.	744	693	673	681
14	1943	Chino	1.25	1.12	0.97	—	0.16	1,165	1,148	983	—

TABLE III—THE SIZE OF SWEET CORN EARS ON DIFFERENT SUCKERING TREATMENTS

Number	Year	Location (Nearest City)	Husked or Unhusked Ear	Size of Ears (Pounds)				
				No Suckering	Early Suckering	Weekly Suckering	Late Suckering	Significance
1	1940	Davis	Husked	0.22	0.20	0.21	0.23	N. S.
2	1941	Davis	Husked	0.42	0.40	0.41	0.41	N. S.
3	1941	Davis	Husked	0.51	0.51	0.50	0.51	N. S.
4	1941	Los Angeles	Unhusked	0.68	0.69	0.71	0.65	N. S.
5	1941	Los Angeles	Unhusked	0.74	0.68	0.74	0.77	N. S.
6	1941	Los Angeles	Unhusked	0.64	—	0.64	—	N. S.
7	1942	Davis	Unhusked	0.34	0.35	0.33	0.36	N. S.
8	1942	Davis	Unhusked	0.43	0.46	0.44	0.44	N. S.
9	1942	San Diego	Unhusked	0.56	0.58	0.62	0.56	N. S.
10	1942	Indio	Unhusked	0.56	0.58	0.56	0.54	N. S.
11	1942	Terminous	Unhusked	0.46	0.43	0.44	0.44	N. S.
12	1943	Fresno	Unhusked	0.64	0.63	0.62	—	N. S.
13	1943	San Diego	Unhusked	0.59	0.62	0.62	0.59	N. S.
14	1943	Chino	Unhusked	0.66	0.68	0.71	—	N. S.

TABLE IV — THE WEIGHTS OF AIR-DRY PLANTS TAKEN FROM THE VARIOUS SUCKERING TREATMENTS

Year	Variety	Pounds of Air-Dry Plant Per Plot (1/300 Acre)*			
		No Suckering	Early Suckering	Weekly Suckering	Late Suckering
1940	Golden Bantam	50.4	36.9	17.1	13.3
1941	Golden Cross Bantam	29.7	22.1	14.9	14.1
1941	Oregon Evergreen	36.8	25.2	21.1	19.5
1942	Golden Cross Bantam	27.0	21.6	15.8	15.7
1942	Oregon Evergreen	37.5	28.9	26.0	26.3

*Least significant difference 7.2 pounds.

suckering treatment. Further studies are to be made upon irrigation and planting distance as affecting this practice.

One advantage to suckering that has been observed is greater ease of harvesting especially where favorable conditions have produced luxuriant stalk growth. However, the cost of suckering cannot be justified on this basis since the actual saving in cost of harvesting is usually slight.

CONCLUSIONS

According to tests conducted on irrigated sweet corn, over a period of 4 years and in seven counties, neither the yield, nor the number of ears per plant, nor the ear size is improved by suckering. Therefore, suckering appears to be an unjustified practice that adds considerably to the cost of production without gaining a commensurate return to the grower.

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Quality Changes During the Storage of Consumer Packages of Sweet Corn and Lima Beans: Progress Report[1]

By L. E. Scott and C. H. Mahoney, *University of Maryland, College Park, Md.*

In order to most efficiently utilize consumer packages for the marketing of fresh vegetables, it is desirable to prepare the product for consumer use before packaging. This study was undertaken to determine the quality changes incurred in sweet corn and lima beans which had been thus prepared and held in consumer packages for varying periods of time at several temperatures.

Materials and Methods

Sweet Corn:—Ears of Golden Cross Bantam sweet corn were harvested, husked, trimmed, washed, packaged, and placed in cold storage within 6 hours after harvest time. The packages used were cellophane-window, wax-impregnated, cardboard cartons holding six ears, and fastened with a simple interlocking device. The storage temperatures were maintained in cabinets controlled to 0.5 degrees F variance at 32, 35, 38, 42, and 46 degrees. The lot of ears used in the test were carefully selected with regard to uniformity of maturity. One-half of each storage lot was precooled for 20 minutes in agitated iced water (34 degrees F) before packaging. Ears were removed for analysis at the end of 2, 6, 8, and 13 days. Total solids, alcohol insoluble solids, and reducing and total sugars were determined on kernels cut off with a mechanical cutter. A "fresh harvest" sample to give initial analytical values were analyzed immediately after the ears were husked and trimmed. At the end of 13 days storage, samples from each of the lot were graded for appearance and quality before and after cooking by boiling.

Lima Beans:—Lima beans of the variety Clark's Bush were harvested with a bean plow, and shelled in a commercial viner. Beans of sieve size No. 3 were washed, packaged, and placed in the storage cabinets within 6 hours after harvest. Two types of packages were used, one was similar to that used in the corn tests, but smaller, holding about 1 pound; the other was a vapor tight, sealed freezer package. The results reported pertain to the unsealed packages unless otherwise stated. One lot of beans for each storage was precooled in agitated iced water (34 degrees F) for 30 minutes before packaging. The storage cabinet temperatures were maintained at 28, 32, 35, 38, 42, and 46 degrees. Sample cartons were removed for determination of total solids, alcohol insoluble solids, and ascorbic acid after the 2nd, 4th, 6th, 8th, and 11th day of storage. Analyses were made on samples from the four lower temperatures only since the beans held at 42 degrees and 46 degrees were obviously unmarketable after the first few days of storage. A "fresh harvest" sample to give initial values was taken and analyzed immediately after the beans were graded and

[1]Scientific Paper No. A-127, Contribution No. 2015 of the Maryland Agricultural Experiment Station (Department of Horticulture).

washed. On the 4th, 6th, 8th, and 11th day of storage samples were taken for observational and cooking tests.

Results

Sweet Corn:—At the end of the 13-day storage period the precooled and non-precooled lots stored at 32 degrees and the 35 degrees precooled lot were excellent in appearance, tender, and would grade as good marketable corn before cooking and of very good quality after cooking. The 35 degrees non-precooled lot and the 38 degree precooled lot had lost sweetness, showed slight indentation, were more starchy, but were still in acceptable market condition. The 38 degree non-precooled, and the 42 degree and 46 degree lots, both precooled and non-precooled, were beyond marketable condition.

The total solids determination showed practically no difference in the moisture content of the various lots over the storage period. Any tendency shown was toward a higher moisture content with both increasing storage time and increasing temperature. Similarly there were no significant changes in the alcohol insoluble solids content.

Sugar analyses of the samples showed decreasing sugar content with increasing length of storage period and with increasing temperatures, and a higher sugar content of the precooled lots. This change occurred entirely in the sucrose (total minus reducing sugars) fraction since there was a slight but significant increase in reducing sugars during the storage period. The sucrose values of the various lots are given in Table I. It will be noticed that the 32 degrees precooled and

TABLE I—Sugar Content of Sweet Corn After Storage in Consumer Packages. (Per Cent Sucrose on Fresh Weight Basis)

Length of Storage Period (Days)	Stored at Temperatures Indicated					
	32 Degrees F		38 Degrees F		46 Degrees F	
	Precooled	Non-precooled	Precooled	Non-precooled	Precooled	Non-precooled
None	2.82	2.82	2.82	2.82	2.82	2.82
2	2.45	1.71	2.47	2.29	1.64	1.32
4	2.41	1.47	1.69	1.72	1.90	0.86
6	2.22	1.68	2.07	1.49	1.35	0.71
8	1.89	2.11	1.59	1.93	0.99	0.65
13	1.53	1.61	1.58	1.39	0.71	0.76

non-precooled lots and the 38 degrees precooled lot retained somewhat more than half of the original sucrose content after thirteen days storage. These lots were of acceptable market and edible condition at this time.

Lima Beans:—At the end of 4 days' storage, beans from both precooled and non-precooled lots held at 28, 32, and 35 degrees were excellent in appearance, free from off odors, and were of very acceptable flavor after cooking. The 38 degree lots were of questionable acceptability and the 42 and 46 degree lots had a definite off taste and odor. At the end of 6 days storage the 28 and 32 degree lots and the 35 degree precooled lot remained fresh in appearance and acceptable after cooking. The other lots were becoming slimy and off

in odor. At the end of 8 days about the same condition was noted, and at the end of eleven days the 28 and 32 degree lots were still of acceptable quality and appearance before and after cooking, with the precooled beans somewhat better than the non-precooled. Ice crystals formed in the packages held at 28 degrees but the beans were not frozen.

The sealed freezer packages were examined on the fourth and eighth days of storage. These lots seemed to retain their color better than the beans in the other packages, and to remain free from slime development for a longer period. However, the sealed packages developed a sweetish odor which held over in the cooked product and caused a definitely undesirable flavor.

The objective quality tests (of the nonsealed package lots) showed, as with the sweet corn, no significant changes occurring either in moisture content or in alcohol insoluble solids. The ascorbic acid values of the lots held at the four lower temperatures are given in Table II. Ascorbic acid decreased during storage from a "fresh harvest" content of 28 mg to about 19 mg per 100 grams at the end of 11 days storage, or a loss of about 33 per cent. More than half of this loss occurred during the first 2 days of storage. There was no difference in the amount of loss occurring at the four different temperatures. The ascorbic acid data show slightly lower values for the precooled lots than for comparable non-precooled lots. This fact may possibly be accounted for by loss of ascorbic acid during the 30 minute immersion in the iced water, or by the higher moisture content of the precooled beans.

TABLE II—ASCORBIC ACID CONTENT OF CLARK'S BUSH LIMA BEANS AFTER STORAGE IN CONSUMER PACKAGES. (MG. PER 100 GRAMS FRESH WEIGHT)

Length of Storage Period (Days)	Stored at Temperatures Indicated							
	28 Degrees F		32 Degrees F		35 Degrees F		38 Degrees F	
	Pre-cooled	Non-precooled	Pre-cooled	Non-precooled	Pre-cooled	Non-precooled	Pre-cooled	Non-precooled
None	28.1	28.1	28.1	28.1	28.1	28.1	28.1	28.1
2	21.9	24.6	24.2	24.2	21 4	24.4	21.9	24.6
4	20.9	24.9	23.4	24.2	22.0	21.8	23.1	25.3
6	21.9	23.7	20.1	22.4	19.7	21.4	22.3	23.0
8	20.1	21.2	19.2	21.5	19.3	21.5	19.3	19.5
11	18.0	19.0	18.9	20.4	18.6	19.9	18.6	18.9

Note: Lots above and to the left of dividing line in the table were of acceptable quality after storage.
Lots below and to the right of dividing line were not of acceptable quality.

SUMMARY

Golden Cross Bantam sweet corn remained in good marketable condition for 13 days, when packed in cellophane-window cardboard cartons, and held in 32 and 35 degrees storage. Clark's Bush lima beans remained in acceptable edible condition for 11 days when held

at 28 or 32 degrees storage. Precooling in iced water improved the storage quality of the products in all instances.

More than half of the original sucrose content of the sweet corn was retained after 13 days storage at 32 degrees. The lima beans retained about two-thirds of their original ascorbic acid content. The greatest loss of ascorbic acid occurred during the first part of the storage period.

Germination of Sweet Potato Seed as Affected by Different Methods of Scarification[1]

By J. A. Martin, Jr., *Clemson Agricultural College, Clemson, S. C.*

During the preliminary phase of the sweet potato breeding project at Clemson Agricultural College, Steinbauer's method of seed coat scarification was used in an effort to obtain a high percentage of germination (1). Briefly, this method consists of soaking the seed in concentrated sulphuric acid for 20 minutes and immediately washing them in warm water. Although this method resulted in a high percentage of seedlings in most cases, germination was poor in others. Thus, a further study of seed coat scarification seemed desirable. The results of certain scarification treatments are presented.

Materials and Methods

Seeds of 11 open pollinated varieties were used. In the case of five varieties the seeds were 9 months old while those of the remaining six varieties were 4 years old.[2] The number of seeds produced by each variety was small. The treatments compared were (a) soaking in concentrated sulphuric acid, specific gravity 1.84; (b) mechanical abrasion, and (c) no treatment. In the sulphuric acid treatment, 15, 30, 45 and 60-minute periods of soaking were followed by immediate rinsing in warm tap water. In the abrasive treatment, each seed was held with forceps so that the two jaws were against the convex and funicular sides respectively, and was pressed against an emery wheel turning at the rate of 1750 rpm (Fig. 1). Care was taken to remove only portions of the seed coat and to avoid injury to the embryo.

To insure prompt germination, the seeds were planted immediately after treatment, in sandy loam in flats placed on a greenhouse bench. The soil was kept moist and at a temperature varying from 80 to 85 degrees F by means of No. 19 lead covered, thermostatically controlled, soil heating cable. Most of the seeds germinated within 3 or 4 days after planting, and counts of the seedlings were made one week after planting.

Discussion

The data presented in Table I show the results of the scarification treatments on the germination of the 9-months-old seed. It will be noted that the seed of variety No. 86 failed to respond to any great extent to any period of soaking, that seed of No. 17 responded remarkably well to the 30, 45 and 60 minute periods of soaking, and that seed of Nos. 16 and 26 were definitely injured by the 60 minute soaking period. Apparently, seed of different varieties may be expected to respond differently to soaking in sulphuric acid. However, the overall

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[1]Technical contribution No. 135 from the South Carolina Agricultural Experiment Station, Clemson, S. C.

[2]The author is indebted to Dr. J. B. Edmond for supplying the 4-year-old seed used in these studies.

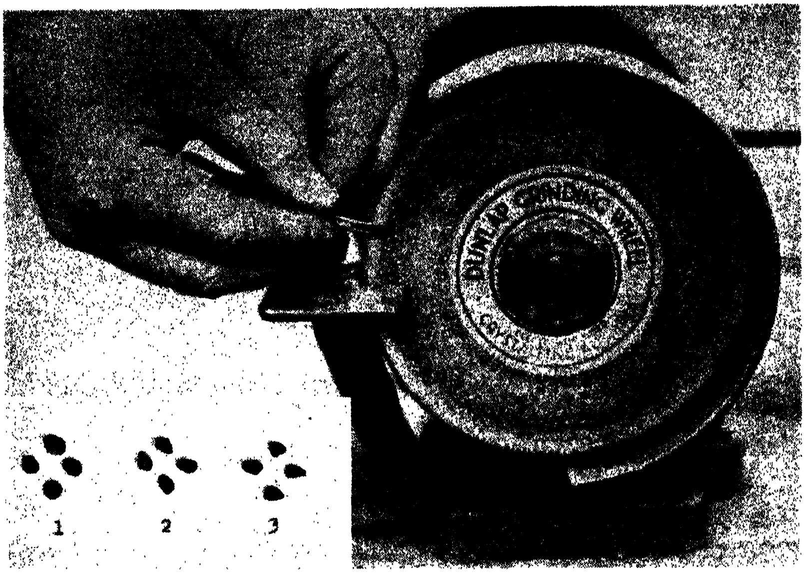

FIG. 1. Abrasion of the seed soat. Seeds were notched by the use of a grinding wheel. Each seed was held against the grinding wheel with forceps until the seed coat was notched as desired. Insert:—Illustration of how much of the seed coat may be notched or ground away. (1) Seed untreated, (2) Seed coat slightly notched (the most desirable), and (3) Seed coat notched too deeply.

results show that a soaking period of 45 minutes resulted in a higher percentage of germination than did the other periods.

As was true of the sulphuric acid treatments, there were differences in response to abrasion of the seed coat. Seed of varieties Nos. 16, 17 and 86 responded exceptionally well to this treatment. Abrasion resulted in a higher percentage of germination in these cases than did any of the sulphuric acid treatments. However, varieties Nos. 26 and 67 responded only moderately well to abrasion. Although there were varietal differences in response to this treatment, on the whole it

TABLE I—EFFECT OF SOAKING IN SULFURIC ACID AND MECHANICAL ABRASION ON THE GERMINATION OF NINE MONTHS OLD SEED OF FIVE VARIETIES OF SWEET POTATO

Variety Number	No. Seeds Planted Per Treatment	Percentage Germination When Indicated Seed Treatments Were Used					
		None	Soaking in Sulphuric Acid				Mechanical Abrasion
			15 Minutes	30 Minutes	45 Minutes	60 Minutes	
16	48	47.9	35.4	60.4	81.3	60.4*	85.4
17	25	8.0	16.0	88.0	92.0	96.0	100.0
26	38	36.8	50.0	89.5	94.7	65.8*	89.5
69	96	34.4	40.6	52.1	64.6	64.6	59.4
86	43	74.4	69.8	74.4	79.1	79.1	90.7
Average	—	41.60	43.60	66.80	77.60	69.60	78.40

*Treating the seeds of these lots with sulphuric acid for one hour caused death of some embryos.

resulted in a higher percentage of germination than did soaking in sulphuric acid, except in the case of the 45 minute soaking period which was as effective on the average as the abrasion treatment.

The data presented in Table II show the affect of scarification on the germination of the 4-year-old seed. Here again, varietal differences in response to the two methods of seed treatment were evident.

TABLE II—EFFECT OF SOAKING IN SULPHURIC ACID AND MECHANICAL ABRASION ON GERMINATION OF 4 YEAR OLD SEED OF SIX VARIETIES OF SWEET POTATO

Variety Number	No. Seeds Planted Per Treatment	Percentage Germination When Indicated Seed Treatments Were Used		
		None	Soaking in Sulphuric* Acid for 60 Minutes	Mechanical Abrasion
Porto Rico (Unit 1)	35	51.4	88.6	97.1
211	20	30.0	75.0	95.0
223	20	75.0	90.0	95.0
228	35	51.4	77.1	82.9
235	30	53.3	83.3	96.7
245	18	50.0	75.0	75.0
Average	—	51.89	83.54	92.40

*No damage observed from soaking sweet potato seed in sulphuric acid for one hour.

The response of seed of variety No. 245 was the same to both the sulphuric acid and abrasion treatments while the response of seed of varieties Nos. 235 and 211 was much greater to abrasion than to soaking for 60 minutes in concentrated sulphuric acid. Despite these lot differences, the average results show that mechanical abrasion resulted in a higher percentage of germination than soaking for 60 minutes in sulphuric acid.

In general, the germination of the 4-year-old seed was very satisfactory. It had been stored in Manila envelopes in a steel cabinet in a room adjacent to a greenhouse. The high percentage of germination obtained in these studies indicates that sweet potato seed may be successfully stored in a dry place for a relatively long period.

CONCLUSIONS AND SUMMARY

1. Nine-months-old and 4-year-old seed of 11 open pollinated varieties of the sweet potato were scarified by soaking in sulphuric acid, specific gravity 1.84, and by abrasion with an emery wheel. The seed was planted in warm, moist soil and the response to scarification was measured by observing the number of the resulting seedlings.

2. Although response to soaking in sulphuric acid and to abrasion varied, the average results showed that when 9-months-old seed were soaked for 45 minutes in sulphuric acid a higher percentage of germination resulted than when the seed were soaked for 15, 30 or 60-minute periods; and that abrasion of this seed was equally effective. In the case of 4-year-old seed a higher percentage of germination, resulted from abrasion than from soaking in sulphuric acid for 60 minutes.

3. In general, the results indicate that where considerable quantities

of sweet potato seed are involved the seed can be more advantageously scarified by soaking in concentrated sulphuric acid than by abrasion, and that a 45 to 60 minute period is more effective than soaking for a shorter period. On the other hand, where a high percentage of germination is desirable and time is not a factor, scarification by abrasion may be used to advantage. When the seed are scarified by abrasion care should be taken to avoid injury to the embryo.

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The Flowering and Fruiting of the Sweet Potato under Greenhouse Conditions[2]

By J. B. EDMOND[1] and J. A. MARTIN, JR., *Clemson Agricultural College, Clemson, S. C.*

INVESTIGATIONS on the breeding and improvement of the sweet potato began at Clemson Agricultural College in 1936. An important phase of the work is the development of new types and varieties by the sexual method of plant breeding. Naturally, the sexual method requires the production of flowers, fruit and seed of the sweet potato plant—a phase of plant behavior that rarely occurs under field conditions in continental United States. From 1936 to the present time methods of greenhouse management have been developed by which a number of varieties, seedlings and introductions have produced flowers and seed more or less satisfactorily. Since certain investigators are interested in producing sweet potato seed in their breeding and improvement programs, a description of the methods used at Clemson may be helpful and is reported herein.

THE GREENHOUSE AND ITS EQUIPMENT

The greenhouse was built in 1936, with its long axis in the northeast southwest direction and is of the semi-iron, truss-frame, even span, detached type. It is 100 feet long and 33 feet wide, has a concrete foundation and concrete walls, continuous side vents and discontinuous roof vents on both sides. The use of side and roof vents are both necessary to provide adequate ventilation. This is particularly true in hot weather.

The house is heated by steam. A 4-inch feed line enters the northeast end and runs to the southwest end where it forms two lines in opposite directions, each of which serve 4–1¼ inch, vertically arranged, heating coils. One set runs along the east wall and the other set runs along the west wall. A Barberton and Coleman thermostatically controlled automatic valve, installed at the head of the feed line, is used to admit or shut off the steam into the house. In general, the use of an automatic valve is more satisfactory than that of manually controlled valves, since it is more reliable and maintains more uniform night and cloudy day temperatures.

The house has two benches, one on each side, and four beds located in the center. Each bench is 100 feet long, 4 feet wide, 3 feet above ground level, and is equipped with No. 19 lead covered, thermostatically controlled, electric soil heating cable. These benches are used to germinate sweet potato seed and to produce vine cuttings from seedlings and plants from fleshy roots. Each bed is 45 feet long and 9 feet wide and is used for the production of flowers and seed. The top soil is 9–10 inches deep, consists of a mixture of 2 parts clay loam and 1 part sand, and is underlaid by a deep layer of stiff clay. In general, beds are

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[1]Now located at Experiment, Georgia.
[2]Technical Contribution No. 137 of the South Carolina Experiment Station.

more satisfactory than benches for seed production, since they provide for greater vine growth and facilitate growing and breeding operations.

Because most lots produce an extensive top system, the vines are trained on substantially constructed, relatively heavy wire. In the Clemson greenhouse the use of 6 foot strands of pig fencing in rows 30 inches apart has been very satisfactory. For each row, two strands are arranged in the vertical position and are supported at the top by wire attached to the cross beams of the house and at the ends by 1¼ inch pipe posts (see Fig. 1). Miller (2) has found that the use of a vertical trellis is favorable to flower and seed production in the sweet potato. Wooden boards 1 by 12 inches are placed between the rows mainly to reduce packing of the soil during pollination and cultural operations (see Fig. 1).

FIG. 1. General view of greenhouse showing arrangement of sweet potato vines on vertical trellis. Plants were set on August 15, 1945. Photograph taken on December 21, 1945.

Water may be applied by running a regulated stream through a hose into shallow furrows situated about 6 inches from and parallel to each row or by using oscillating overhead Skinner irrigation lines equipped with greenhouse nozzles. The former method was used from 1936 to 1944 and the latter method is used at the present time. Of these methods the use of irrigation lines is more labor saving than that of the furrow method. However, from the standpoint of plant growth, both methods are satisfactory. Since the sweet potato has glossy foliage the spraying of water on the vines has no harmful effects.

Greenhouse Management

The management of the greenhouse may be divided into four more or less distinct periods: (a) soil preparation, (b) variety arrangement and establishment, (c) vine growth and development and (d) flower and seed production.

Soil Preparation:—The principal practices are partial sterilization of and incorporation of barnyard manure and commercial fertilizers in the soil. These are best done about the middle of July. Prior to soil sterilization, all weeds, plant refuse and trash are collected and burned, and all repairs to the beds, benches, heating and watering systems are made. To partially sterilize the soil, steam was used from 1937 to 1943 and chloropicrin was used from 1944 to the present time. Partial sterilization with steam consisted of keeping the soil moist for a period of 1 week before the steam was applied, running steam through lines of nonperforated 4-inch drain tile, and in firming the soil directly above the tile lines. The tile lines are 28 inches apart, run the full length of the house and were placed just below the surface of the subsoil. To prevent the gradual sifting of soil into and to permit the flow of steam from the tile lines, coarse gravel was placed over the joints of the tile at the time the lines were laid. During sterilization a pressure of 13 to 15 pounds of steam was maintained at the boiler and one line of tile was sterilized at a time. Since each line required a period of 5 hours to bring the soil to the required temperature, and since 8 lines of tile were necessary to sterilize the four beds, the operation required a period of 4 days.

Partial sterilization with chloropicrin consists of keeping the soil moist for a period of 1 week before the chemical is applied, placing 6 cubic centimeters of the liquid in holes 4 inches deep and in staggered rows 10 inches apart, wetting down the surface of the soil to seal in the gas, and closing all doors and vents immediately after the chloropicrin is applied. The liquid is applied by means of a Larvaecide applicator and the operator should preferably wear a mask adapted to Larvaecide applications. Immediately after the chemical is applied all doors and vents are closed and kept closed for a period of 1 week. At the end of this period because the gas is highly concentrated in the house, only the doors are opened at first. About 4 or 5 hours later the top and side vents can be opened without undue risk to the operator. Of the two methods the use of chloropicrin is decidely more economical and considered as effective in disease and insect control as the use of steam.

The incorporation of organic matter and commercial fertilizer consists of placing a uniform layer of well decomposed barnyard manure and a broadcasted application of a complete mixture on the surface of the soil and spading these materials into the soil at least 2 weeks before the plants are set. The manure is applied at the rate of one wheel-barrow load per 25 square feet, and the commercial fertilizer is applied at the rate of 3 pounds per 100 square feet. In general, mixtures low in nitrogen and high in phosphorus and potassium are used, such as 1–12–10. After spading, the soil is kept moist to permit the rapid decomposition of the manure and the formation of nitrates.

Variety Arrangement and Establishment:—The arrangement of the varieties or breeding lots is largely dependent on the number which are to be crossed. In general, any two parents of a given cross should be planted in adjacent rows opposite each other. In this way, time is saved in pollination operations and the two parents are grown under fairly comparable conditions. On the other hand, lots which are to be selfed may be planted with little regard to their proximity to other lots.

The establishment of the plants consists of taking vine cuttings from disease free plants in the field and in rooting them in sand or sandy loam in a greenhouse bench about 1 week before they are placed in the beds, or in planting the cuttings directly in the beds as they come from the field. Either method is dependable and satisfactory.

During the period of recovery from the check in growth incident to transplanting, particular attention is necessary toward maintaining a moist soil and to providing for maximum ventilation. In the Clemson greenhouse the vine cuttings are set in the beds during the second and third week of August, lime is applied to the greenhouse roof and all doors, windows and vents are opened.

Vine Growth and Development:—The growth habit of the sweet potato is indeterminate. In general, two phases of growth are discernible: (a) the development of absorbing roots, stems and leaves, and (b) the simultaneous development of fleshy roots, absorbing roots, stems and leaves; and flowers and fruit. In the first phase of growth, utilization of carbohydrates is dominant over accumulation and environmental factors are manipulated accordingly. Thus, night temperatures are maintained on the upper level of the optimum range for growth, and the light, moisture and nutrient supply are held at comparatively high levels. In this way, there is a rapid rate of cell division and vegetative extension during the night, and a high rate of photosynthesis during the day. In the Clemson greenhouse, rapid root and vine growth has been attained by setting the plants 24 inches apart; maintaining night temperatures from 73 to 75 degrees F, cloudy day temperatures from 75 to 80 degrees F, and sunny day temperatures from 80 to 95 degrees F; keeping the soil moist from the time the beds are spaded to the time the vines have developed sufficiently for adequate flowering and fruiting; sprinkling down the walks and beds with overhead irrigation lines during sunny days; and allowing lime to remain on the greenhouse roof from the time the plants are set to about October 1 when it is removed by the combined use of water from a hose and a long handled scrubbing brush.

Cloudy day temperatures above 80 degrees F and wilting of the vines, particularly during August and September, should be avoided. The use of water to increase the humidity in the greenhouse during the warm part of the day, and the use of lime to reduce light intensity will maintain turgor and reduce wilting to a minimum.

Flower and Seed Production:—During the flowering and fruiting stage the accumulation of carbohydrates is dominant over utilization. Thus, night temperatures are maintained within the lower half of the optimum range for growth, the light supply is kept at a maximum and

the water, and nutrient supply are held at comparatively low levels. In the way, there is a slowing down in the rate of cell division and vegetative extension. This combined with a high rate of photosynthesis permits accumulation of carbohydrates and the formation of flower forming substances. In the Clemson greenhouse and after the vines have attained sufficient bearing surface, flowering and fruiting have been induced in most of the lots by maintaining night temperatures from 60 to 63 degrees F, cloudy day temperatures from 65 to 70 degrees F, and sunny day temperatures from 70 to 85 degrees F; combined with holding the plants on the "dry side"; and keeping all shade from the greenhouse roof. Under these conditions the lower leaves gradually become yellowish-green, flower buds appear about October 15, and the vines produce flowers and fruit until the following spring.

This response of the sweet potato suggests that length of day, light intensity, temperature, moisture and nutrient supply influence both the vegetative, and the flowering and fruiting stages of growth and development. Long length of day and high light intensity combined with high temperatures and high moisture and nutrient levels make for rapid vegetative growth and, little if any, flower production. On the other hand, short length of day and low light intensity combined with comparatively low temperatures and low moisture and nutrient levels make for flower, fruit and seed production. Although all of these factors undoubtedly interact with each other, according to our observations, length of day seems to be the most effective in flower and fruit production. In fact, a length of day of from 11½ to 12½ hours appeared to be optimum for most seedlings and varieties under observation. Thus, the sweet potato may be classified as a short day plant.

Control of Pests

Principal pests encountered in the Clemson greenhouse have been red spider, aphid, a leaf caterpillar and mealy bug. Aphids are controlled by fumigating on calm nights with nico-fume at intervals of 10 days. Red spiders and mealy bugs are controlled by systematically inspecting all plants in adjacent greenhouses and arranging for the eradication of infested plants or for red spider or mealy bug control, and by alternately spraying the sweet potato vines at weekly intervals with water and Yamtox, a proprietary compound. Yamtox does not injure the foliage. The leaf caterpillar is controlled by using a dust or spray containing calcium arsenate.

Aschochyta leaf spot has been observed on poorly vigorous, weakly vegetative plants. Since this disease is not serious no control measures have been practiced.

Flowering and Fruiting Habits

The inflorescence of the sweet potato is axillary and consists of a single flower or a cluster of two or more flowers on stout 4 to 6 inch peduncles. The individual flower is hermaphroditic and resembles that of the morning glory. The trumpet shaped corolla ranges from 1.0 to 1¾ inches in transverse diameter and varies from nearly white to a

delicate pink with a light or dark purple throat. The five stamens are attached to the base of the corolla and vary in height with reference to the position of the stigma. For example, in 1939–40 some lots had two stamens with anthers above the level of the stigma and three stamens with anthers below; other lots had two stamens with anthers at the same level as the stigma and three stamens with anthers below; and other lots had all five stamens with anthers below the level of the stigma. The superior pistil consists of a small round ovary, a long slender style and a bilobed stigma.

In general, the flowers open just before, at or immediately after sunrise and close on the same day—in early afternoon in sunny weather and in late afternoon or night in cloudy weather. The anthers dehisce longitudinally just before or immediately after the flower opens and the amount of pollen shed varies greatly with the seedling or variety, the number of opened flowers on any given vine and the character of the day. A high humidity in the greenhouse is believed to facilitate shedding of the pollen. Honey bees work satisfactorily among the flowers and have been used at Clemson to produce open-pollinated seed. The stigmatic surface of the pistil appears to be most receptive between 8 a. m. and 10 a. m.

A wide variation has been observed among the various lots in vigor of foliage, in production of flowers and in setting of fruit. Some lots have produced abundant flowers and set most of their fruit, others have produced abundant flowers and set very few fruit, others have produced few flowers and set practically no fruit, and others have produced no flowers and no fruit. For example, C-13, a cross between Porto Rico and Nancy Hall, produces a more vigorous vine and more flowers and sets more fruit than either of the parents. Wannop and Creole produce abundant flowers and fruit while Maryland Golden produces no flowers and fruit. Since the roots of Maryland Golden and related types have the desired size and shape, and since they hav failed to produce flowers under the conditions described, the need for further investigations on flowering and fruiting is indicated.

The fruit is a relatively small, round and hairy or non-hairy pod. Under the conditions described it requires about 1 month to attain maturity. Data in Table I show the number of seed in open-pollinated

TABLE I—NUMBER OF SEEDS IN OPEN-POLLINATED AND CROSS-POLLINATED SWEET POTATO FRUIT, 1940

Type of Fruit	Total Number Fruits	Fruits (Per Cent) With			
		One Seed	Two Seeds	Three Seeds	Four Seeds
Open-pollinated	615	67	25	7	1
Cross-pollinated	417	35	53	12	0

and controlled cross-pollinated fruit collected in the spring of 1940. Note that most of the fruit contained one or two seed and that very few contained three or four seed. In general, open-pollinated fruit contained lesser seed than controlled cross-pollinated fruit.

The mature seed is medium large, angular and has a hard black or

brown coat. For prompt germination of the embryo the hard coat requires scarification. From 1938 to 1943 Steinbauer's method (3) was used successfully. Briefly, this method consists of soaking the seed in concentrated sulphuric acid, (specific gravity 1.84), for 20 minutes and immediately washing the seed in warm water. With this method prompt and vigorous germination of most but not all lots was secured. More recently, Martin (1) has secured a higher percentage of seedlings by soaking the seeds in concentrated sulphuric acid for 45 and 60 minutes and by notching the seed coats with an emery or grinding wheel.

Controlled Pollination and Handling of Seeds and Seedlings

Three materials have been used in making controlled selfings and crosses: paper clips, pill boxes and soda straws. Paper clips were first used by Miller,[3] pill boxes by the junior author and soda straws by Hughes.[4] At present, paper clips are used to protect the flowers in controlled selfings and the flowers of the male parent in controlled crosses, and pill boxes and soda straws are used to protect the flowers of the female parent in controlled crosses. In selfing and protecting the flowers of the male parent in crosses, a large paper clip is placed on the tip of an about to be opened flower in late afternoon (see Fig. 2). The next morning the clip is removed, a stamen is removed with forceps and the anther is gently tapped on the stigma of the selfed flower or on the stigma of the female parent. This transfer of pollen may be repeated with the other stamens until sufficient pollen has been placed on the stigma. In selfed flowers the corolla may be again closed with the paper clip or the flower may be placed in a pill box. In general, paper clips are less satisfactory than pill boxes since they sometimes fail to keep the corolla closed and are easily knocked off by spraying and other cultural operations.

Emasculation of the female parent is performed on about to be opened flowers between 2 p. m. and 6 p. m. and is accomplished by slitting the corolla into two equal parts from the tip through the sepals to the receptable with the corners of a razor blade, and by taking each half of the corolla between the thumb and forefinger and gently pulling out and down. In this way, the corolla with the attached stamens is removed, the pistil becomes exposed and is enclosed in a pill box or soda straw. In using the pill box, a small notch is cut on one end of the box just large enough to accommodate the peduncle. The emasculated flower is placed in the box, the peduncle is laid in the notch and the cover is slid over the flower until the box is completely closed (see Fig. 2). In using the soda straw, each straw is cut into 6 equal lengths and a section is slipped over the pistil with one hand while the sepals are held with the fingers and thumb of the other. The tip of the straw is then bent over to prevent the entrance of insects (see Fig. 2).

Pollination of the female parent consists of removing the pill box

[3]Miller, J. C., Personal correspondence, 1938.
[4]Hughes, M. B., Personal conversation, 1945.

FIG. 2. The flowering habit of the sweet potato and the use of paper clips, pill boxes and soda straws in controlled pollination.

or straw, applying pollen of the male parent, replacing the pill box or straw and tagging the flower. Two days later, the pill box or straw is removed to permit uninterrupted growth of the ovary. Used straws are discarded and since pill boxes are more expensive they are saved and dipped in 70 per cent ethyl alcohol to destroy any pollen grains which may be present. Fig. 2 shows the flowering habit of the sweet potato and the materials used in pollination practices. Data in Table II show that selfing is less successful in seed production than crossing. In this case several seedlings and introductions were compared.

TABLE II—SELF AND CROSS-POLLINATED SWEET POTATO FLOWERS SETTING FRUIT, 1939–40

Method of Pollination	Total Number Flowers		Fruit Set (Per Cent)
	Pollinated	Setting Fruit	
Selfing; between plants of same variety	858	25	1.5
Crossing; between plants of different variety	2,194	812	37.0

The fruits are harvested just after they have reached maturity and are stored in Manila envelopes in a dry place at room temperature until the seed is treated and planted. In most cases, very few seed have been secured from a given selfing or cross; hence a rapid multiplication of plants is necessary. Fortunately, the sweet potato is well adapted to asexual propagation. The following method has been developed at Clemson for the propagation of seedlings. The seed of all selfings and crosses are saved until the first part of April, then they are scarified with sulphuric acid or an emery wheel and planted in warm-moist soil, maintained from 75 to 85 degrees F. About 1 week after the seedlings appear they are transplanted 6 inches apart in rows 12 inches apart in sandy loam in the greenhouse bench or bed. As the seedlings grow cuttings consisting of three or four nodes may be made and planted in the greenhouse or the seedlings may be allowed to grow and vine cuttings made just before they are set in the field. With these procedures a single plant will produce sufficient vines for five or six cuttings which will be ready for planting to the field by the third week of May. These plants in turn will produce sufficient seedstock for the production of plants the following year.

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Effect of Date of Planting and Time of Harvesting on the Carotene Content of Sweet Potatoes of the Porto Rico Variety

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An important constituent of the yellow- or orange-fleshed varieties of sweet potatoes, from a nutritional standpoint, is the carotene content. The carotene content of various varieties of sweet potatoes is known to differ and that of a given variety to be somewhat variable (2). Anderson and others (1) report that potatoes grown from plants set out from June 28 to July 13 had a lower carotene content at harvesting time that those planted April 15 to June 4. The harvest of sweet potatoes begins in the lower South in July and continues into November. Potatoes dug before the middle of September are usually not stored. The experiment here reported was conducted to obtain information on the variation of carotene content in sweet potatoes during the growing season.

Sweet potato slips of the Porto Rico variety were set out at four different planting dates and samples for carotene analysis were dug at monthly intervals beginning approximately 3 months after setting to the field. Plants were set out one foot apart in rows 4 feet wide. Planting dates and digging times are given in Table I. At the time the last digging was made there had been no injury to the plants from cold. The 1945 growing season was a rather wet one as shown by the precipitation data given in Table III. Sweet potato yields are likely to be low in wet seasons unless the plants are set to the field fairly early. No yield records were kept until the time of the last sampling. At that time a single row 200 feet in length for each date of planting was dug

TABLE I—Influence of Planting Date and Time of Digging on Carotene Content of Sweet Potatoes of the Porto Rico Variety

Date Analyzed	Per cent Dry Matter	Carotene Mg/100 Grams Moist Weight	Carotene Mg/100 Grams Dry Weight	Approximate Age Months
Planted April 27, 1945				
7/17/45	30.14	4.58	15.18	2 1/2
8/17/45	32.97	7.01	21.25	3 1/2
9/18/45	30.17	7.01	23.24	4 1/2
10/15/45	27.86	4.98	17.88	5 1/2
11/15/45	29.03	5.16	17.77	6 1/2
Planted May 16, 1945				
8/17/45	33.53	6.66	19.85	3
9/18/45	31.21	5.98	19.15	4
10/15/45	31.68	5.86	18.50	5
11/15/45	30.61	5.45	17.80	6
Planted June 14, 1945				
9/18/45	30.76	5.52	17.93	3
10/15/45	30.53	5.57	18.23	4
11/15/45	29.93	5.81	19.43	5
Planted July 6, 1945				
10/15/45	27.60	3.16	11.44	3 1/3
11/15/45	29.39	4.39	14.94	4 1/3

and total yields recorded to give some idea of the effect of the planting dates on yield. Carotene was extracted by the method of Moore and Ely (3) using composite samples obtained from the grated pulp of 10 roots. The adsorption of the petroleum ether extract was measured at 440 mu in a Coleman spectrophotometer and the concentration of carotene calculated from a calibration curve determined with solutions of pure beta carotene.

The analytical data are shown in Table I and the yield data in Table II. The variation in total yields shows that the total production

TABLE II—EFFECT OF PLANTING DATE ON TOTAL YIELD OF SWEET POTATOES OF THE PORTO RICO VARIETY DUG NOVEMBER 15, 1945

Date of Planting	Total Yield (Bushels per Acre)
April 27	631.0
May 16	487.7
June 14	212.2
July 6	111.4

of sweet potatoes was markedly affected by the date of planting. This was to be expected as it has been shown many times previously. The data on carotene content of sweet potatoes show that there was some seasonal variation in potatoes from slips of each of the different plantings. In general the carotene content was lowest at the first sampling of potatoes from an individual planting. At that time the potatoes were likely to be small and very immature. After moderate size had been attained, the size of the sweet potatoes did not appear to affect the carotene content appreciably. The roots of first samplings of potatoes from the May and June plantings were not so small as from the other two plantings. The carotene content of sweet potatoes showed no appreciable differences attributable to the effects of the dates of planting except in the case of the July planting. Potatoes from that planting were lower in carotene content. These results are for one season only and would probably vary somewhat under different climatic conditions. It seems likely, however, that the planting date of potatoes, in south Louisiana, up to the middle of June is not likely to affect the carotene content of roots of marketable size. Early dug sweet potatoes of usable size may be as high or higher in carotene content than those from the same planting date dug later.

TABLE III—RAINFALL FOR PERIOD EXTENDING FROM APRIL 27 TO NOVEMBER 15, 1945

Time	Rainfall in (Inches)	Number of Days When Some Rain Fell
Apr 27–30	0.23	1
May	4.19	7
Jun	5.75	12
Jul	5.19	16
Aug	7.90	13
Sept	4.59	11
Oct	3.76	11
Nov 1–15	0.96	2

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Cooperative Studies of Sweet Potato Plant Production[1]

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IN the past, investigations of the effect of the environment and cultural practices on the plant production of the fleshy roots of the sweet potato have been largely limited to hotbed operations. Very little, if any, experimental information is available on the effect of growing conditions and cultural practices under which the roots are raised and on the effect of environmental conditions under which the roots are cured and stored. The pertinent results of cooperative studies of the effect of nitrogen supply, time of harvest, and certain curing and storage conditions on plant production are reported herein.

MATERIALS AND METHODS

The results were obtained at the Mississippi and South Carolina Agricultural Experiment Stations. In Mississippi all phases of the work were conducted at State College, and in South Carolina the roots were grown and stored at Blackville and the plants were grown at Clemson. The work was begun in the spring of 1941 and carried on continuously in Mississippi until the spring of 1944 and in South Carolina until the spring of 1943.

Unit 1 Porto Rico and Triumph, and the factors under investigation were two levels of quickly available nitrogen, three times of harvest and four curing and storage treatments. The nitrogen levels and times of harvest, together with the type of soil and date of field planting at each of the cooperating stations are presented in Table I.

The curing and storage treatments were: (A) potatoes not artificially cured and stored in a nonheated building, (B) potatoes not artificially cured and stored under recommended conditions of temperature and humidity, (C) potatoes artificially cured and stored in a nonheated building, and (D) potatoes artificially cured and stored under recommended conditions of temperature and humidity. In the no artificial curing and storage in a nonheated room treatment, the temperature and humidity fluctuated with those of the outside air. In the artificial curing and storage under recommended conditions of temperature and humidity treatment, the temperature was maintained from 80 to 85 degrees F during the curing period and from 50 to 55 degrees F during the storage period with a moderately high relative humidity for both periods. The curing period extended for 5 days immediately after the roots were harvested, and the storage period began at the end of the curing period and ended during the last week of March or first week of April — the usual time for taking sweet potatoes out of storage for bedding operations.

[1]Preliminary summary of studies conducted cooperatively by the Georgia, Mississippi and South Carolina Agricultural Experiment Stations, and the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture. A complete report will be published later as a U. S. Department of Agriculture Circular.

The salient features under which the roots were bedded and the plants were grown at each of the two stations are presented in Table I.

TABLE I—CULTURAL AND ENVIRONMENTAL CONDITIONS UNDER WHICH THE PLANT PRODUCTION TESTS WERE CONDUCTED

	Ocklocknee Loam, Mississippi			Norfolk Sandy Loam, South Carolina	
	1941-42	1942-43	1943-44	1941-42	1942-43
Production of Storage Roots					
Date of field planting	May 15	May 14	May 10	May 2	Apr 30
High N (pounds per acre)	80	80	100	40	40
Low N (pounds per acre)	0	0	20	10	10
Date of first harvest	Oct 13	Sep 17	Sep 10	Sep 3	Sep 2
Date of second harvest	Nov 8	Oct 19	Oct 23	Oct 10	Oct 12
Date of third harvest	Dec 1	Nov 14	Nov 15	Oct 31	Oct 31
Production of Plants					
Date roots taken from storage	Apr 3	Mar 29	Mar 30	Apr 19	Apr 8
Date roots bedded	Apr 3	Mar 29	Mar 30	Apr 21-24	Apr 9-10
Type bedding media	River bed sand			Mixture of clay loam and sand	
Days to first plants	24	35	39	21	21
Plant pulling period	Apr 27-May 18	May 3-Jun 1	May 8-Jun 6	May 12-30	May 1-15

To promote rapid plant production, bottom heat was provided through the use of No. 19, lead covered, thermostatically controlled, electric soil heating cable and soil heating thermostats were set to shut off the electricity at 85 degrees F. The roots were watered immediately after they were bedded, then at intervals of 4 to 5 days until the first pulling of the plants, and immediately after each pulling until the experiments were concluded. The first plants were pulled from 21 to 39 days after the roots were bedded and pullings continued at intervals of 5 to 7 days until three or four pullings were made.

The effect of the three factors, nitrogen supply, time of harvest and curing and storage, on plant production was measured in terms of the number of plants produced per 56 pound bushel of bedded roots. The formula used was as follows:

$$\text{Plants per bushel} = \frac{\text{Number of plants per lot x 56}}{\text{Weight of roots per lot (in pounds)}}$$

DISCUSSION

The results, presented in Table II, show significant effects in some cases and insignificant effects in others. At both places Unit 1 Porto Rico produced a greater number of plants per 56 pound bushel than Triumph, and at both places the difference is highly significant. These results agree with the observations of sweet potato specialists and growers and show that Unit 1 Porto Rico has a greater plant producing capacity than Triumph. Since the roots were grown under two nitrogen levels and harvested at 3 different times, and since they

TABLE II—EFFECT OF NITROGEN SUPPLY, TIME OF HARVEST AND CURING AND STORAGE ON PLANT PRODUCTION OF UNIT 1 PORTO RICO AND TRIUMPH SWEET POTATOES

Variety or Treatment	Mississippi 1941–44			South Carolina 1941–43		
	Mean Number Plants Per Bushel	Difference Necessary for Significance		Mean Number Plants Per Bushel	Difference Necessary for Significance	
		5 Per Cent Level	1 Per Cent Level		5 Per Cent Level	1 Per Cent Level
Unit 1 Porto Rico	1,642	154.0	231.0	1,797	56.4	84.6
Triumph	1,172			1,441		
High N level	1,405	60.8	91.2	1,607	58.9	88.3
Low N level	1,408			1,631		
Early harvest	1,511			1,896		
Medium early harvest	1,330	109.6	164.4	1,595	122.0	183.0
Late harvest	1,380			1,366		
Roots not cured; stored in nonheated room (A)	1,316			1,525		
Roots not cured; stored in heated room (B)	1,411	110.2	165.3	1,701	98.1	147.1
Roots cured for 5 days; stored in non-heated room (C)	1,380			1,592		
Roots cured for 5 days; stored in heated room (D)	1,520			1,656		

were cured and stored under a wide range of temperature and humidity, the higher plant producing capacity of Unit 1 Porto Rico may be expected to prevail over a wide range of environmental and cultural conditions.

At both places the two levels of readily available nitrogen had the same effect on plant production. In fact, the means of the high and low nitrogen levels are practically and statistically identical. Evidently, under the conditions of the experiments and with the factors under investigation, the application of high or low quantities of available nitrogen is without effect on the plant production of the bedded roots.

The results show that at both places plant production varied with the time of harvest. In general, roots harvested during the early part of the season produced a greater number of plants per 56 pound bushel than those harvested during the middle or later part. In Mississippi, the mean difference between the first and second harvest is highly significant, that between the first and third harvest is significant, and that between the second and third harvest is insignificant. However, in South Carolina the mean difference between any two harvests is highly significant. Thus, the effect of time of harvest on plant production is appreciable, and the results show that harvesting during the early part of the season is more favorable to plant production than harvesting during the latter part. Apparently, cold weather during the latter part of the harvesting season is unfavorable to plant production.

The results of the four curing and storage treatments show the relative importance of artificial curing and favorable storage on plant production under the conditions of the experiments. Note that at both places the mean differences between favorable storage and unfavorable storage (treatments B minus A, and D minus C) are wider than

those between artificial curing and no artificial curing (treatments C minus A and D minus B). In fact, artificial curing produced significant effects in no instances and favorable storage produced significant effects in two cases out of four, (treatments D minus C in Mississippi and B minus A in South Carolina). The lower plant production of the roots stored in the nonheated room was rather marked and expected, since previous experiments have shown that even a short exposure to comparatively low temperature markedly lowers plant production (1). Thus, while the data indicate that curing and storage are favorable for high plant production, they show that of the two practices, storage under favorable temperature and humidity is the more important and necessary one.

Conclusions and Summary

1. Cooperative studies of the effect of two levels of readily available nitrogen, three times of harvest and four curing and storage treatments on plant production of bedded roots of Unit 1 Porto Rico and Triumph were conducted in Mississippi from 1941 to 1944 and in South Carolina from 1941 to 1943.

2. At both places Unit 1 Porto Rico produced a significantly greater number of plants than Triumph. Since the roots of these varieties were grown under two nitrogen levels, harvested at three different times and stored under a wide variation of temperature and humidity, the higher plant producing capacity of Unit 1 Porto Rico may be expected to prevail under a wide range of environmental and cultural conditions.

3. The two levels of nitrogen had no differential effect on plant production of the bedded roots.

4. In general, roots harvested during the early part of the season produced a greater number of plants per bushel than those harvested during the latter part. In all cases, except one, the roots of any second or third harvest produced a significantly lesser number of plants per bushel than those of the preceding harvest. Apparently, cold weather of the latter part of the harvesting season is unfavorable to high plant production.

5. Since the differences in plant production between favorable storage and unfavorable storage were wider than those between artificial curing and no artificial curing, storage under favorable temperature and humidity seems to be more necessary for high plant production than artificial curing.

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Effect of Selective Petroleum Weed Sprays on the Yield and Flavor of Carrots[1]

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IT HAS recently been shown (1, 2, 4, 5, 6) that certain oils can be used as selective weed sprays to replace part or all of the hand weeding of carrots, parsnips and some other members of the Umbeliferae family. Although these reports have indicated that generally good results can be secured, several difficulties have been encountered. Crafts and Reiber (1) and Raynor (5) state that the rate of application of stove oil must be controlled to avoid injury to carrots. Raynor (5) recommended that carrots have from one to four true leaves when sprayed since carrots in the cotyledon stage have been injured. Sweet, *et al* (6) used various kerosenes and fuel oils and reported serious injury when carrots having only one true leaf were sprayed, but only rare injury when three or more true leaves were present. On the other hand, Lachman (4) using Sovasol No. 5 (a Stoddard solvent) and a mixture of one part Sovasol No. 75 (an aromatic solvent) with two parts white kerosene reported no apparent injury. Grigsby (2) used Sovasol No. 5, Stanisol (a Stoddard solvent), Oleum Spirits and white kerosene and found no significant differences in yield between sprayed and unsprayed carrots.

Another problem in connection with the use of oil sprays is the possible effect on flavor. Raynor (5) indicates that this is a serious problem when stove oil is used on bunching carrots. He states that carrots having more than four true leaves should not be sprayed, due to the danger of retaining flavors in the roots. Crafts and Reiber (1) reported that gasoline (although too dangerous for practical use) dissipated more rapidly from sprayed carrots than stove oil and left no objectionable flavor. Lachman (4) found no flavors in either raw or cooked carrots that had been sprayed three times with Sovasol No. 5 and harvested 2 months after the last spray was applied. Grigsby (2) has recently reported the results of extensive flavor tests on carrots sprayed with trade name Stoddard solvents and with white kerosene. He found no significant differences between sprayed and unsprayed lots.

The purpose of these experiments which were conducted during the 1945 growing season was to determine: (a) the relative effectiveness of several petroleum products available in Wisconsin as selective weed sprays for carrots; (b) the effect of these sprays on the yield of carrots; and (c) the effect of the sprays on flavor.

MATERIALS AND METHODS

The oils used in these experiments and the sources of supply were as follows: Stoddard solvent, aromatic solvent, and No. 3 fuel oil A from Sinclair Refining Company; Oleum spirits and No. 3 fuel oil

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B from Standard Oil Company of Indiana; E–407 (an aromatic solvent), and No. 1 fuel oil from Shell Oil Company; Sovasol No. 75 from Socony-Vacuum Oil Company. In addition to these, several other oils were used in the preliminary tests. Emulsions of oil in water were made by dissolving 0.5 per cent of Triton B–1956 (Rohm and Haas Company) in the oil used and then adding water to give the proper concentration.

The variety of carrots planted was Red Cored Chantenay, and the sprays were applied by means of a small hand sprayer at low pressures. A cloth frame was used around the section of row being sprayed to prevent spray drift to adjacent rows. Only a strip 6 inches wide with the carrot row at its center was treated, and cultivation between the rows was done in the usual manner. Rates of application were based on the actual area sprayed. Spraying was done during a wide variety of weather conditions but since it did not appear to have much effect on the results no weather data are presented. The weeds most commonly encountered were as follows: pigweed *(Amaranthus retroflexus)*, lambs-quarters *(Chenopodium album)*, smartweed *(Polygonum pennsylvanicum)*, purslane *(Portulaca oleracea)*, galinsoga *(Galinsoga cilita)*, ragweed *(Ambrosia artemisiifolia)*, wild mustard *(Brassica arvensis)*, foxtail *(Setaria spp.)* and crab-grass *(Digitaria spp.)* Check plots were hand weeded on the same day that spraying was done. About 2 weeks after the last spray treatments were applied, notes were taken on weed survival and all plots were hand weeded as necessary from this time on. Individual plots consisted of two rows of carrots 10 feet long, but in harvesting 1 foot on each end of the plot was discarded. The carrots were harvested at canning stage in the fall.

Field Results

In preliminary tests it was found that Stoddard solvent, sold under various brand names, gave consistently good results as a selective herbicide for carrots regardless of the source of supply. All of the weeds encountered with the exception of ragweed were easily killed by the spray and there was no apparent injury to the carrots. However, since the cost of this product is somewhat high, it seemed desirable to find a cheaper material if possible. These preliminary experiments indicated that in addition to Stoddard solvent, the following three types of sprays also offered promise, and would be considerably cheaper; (a) No. 3 fuel oil (quite similar in physical characteristics to the western stove oil); (b) emulsions of aromatic solvents in water; and (c) mixtures of aromatic solvents with a No. 1 fuel oil. The aromatic solvents caused severe injury to carrots when used undiluted.

The kerosenes and No. 1 fuel oils available in Wisconsin were found to be too mild to be effective as herbicides. This is in agreement with results reported in Michigan by Grigsby and Barrons (3). Oils with a flash point below 100 degrees F were not used due to their hazardous nature.

Experiments I and II:—The treatments included in these two experiments were randomized within blocks and there were four replications. Carrots in Experiment I were planted April 7 on a loam soil

near Racine, Wisconsin, and were sprayed on June 6, at which time they had from 2 to 4 true leaves. Experiment II was conducted on peat soil at Madison, Wisconsin. The carrots were planted May 4 and spraying was done on June 11 at which time they had from 2 to 3 true leaves. Experiment I was harvested on October 15 and 16 and Experiment II on October 11 and 12.

The results of these two experiments are presented in Table I. Stoddard solvent again gave good results as a selective herbicide for

TABLE I—EFFECT OF SELECTIVE PETROLEUM WEED SPRAYS ON THE YIELD OF CARROTS IN EXPERIMENTS I AND II

Treatment			Observation on Weed Control	Observed Injury to Carrots	Yield of Carrots (Tons Per Acre) (1½-inch Min. Diam.)*	
Material	Concentration	Gallons Per Acre			Experiment I	Experiment II
Stoddard solvent	Undiluted	50	Fair	None	34.9	26.4
	Undiluted	100	Good	None	31.8	23.5
No. 3 fuel oil A	Undiluted	50	Fair	Slight	33.1	28.3
	Undiluted	100	Good	Moderate	33.8	22.7
No. 3 fuel oil B	Undiluted	50	Fair	Slight	29.9	29.4
	Undiluted	100	Good	Moderate	29.8	22.6
Sovasol No. 75	20 per cent**	100	Very poor	None	30.1	24.5
	30 per cent**	100	Poor	None	31.4	26.1
E-407	10 per cent**	100	Poor	None	33.5	27.4
	20 per cent**	100	Fair to good	Slight	31.7	24.5
Check (hand weeded)	—	—	Good	None	31.9	24.2
	—	—	Good	None	32.5	28.0

*No significant difference in yield between any treatments at 5 per cent level.
**Emulsion of oil in water.

carrots and so is used as the standard for comparison of other materials. None of the treatments caused significant reductions in yield. It should be noted that the higher rate per acre or higher concentration in the case of emulsions, was necessary to obtain good control of weeds. Sovasol No. 75, however, did not give satisfactory control of weeds at the highest concentration used.

The No. 3 fuel oils caused considerable injury to the carrots when used at rates high enough to control weeds. In these two experiments, however, injury was not severe enough to reduce the stand. Within 5 or 6 weeks after spraying they had recovered to the point where no differences could be observed in comparison with the check plots and there was no significant reduction in yield. These results might seem to indicate that No. 3 fuel oil would have possibilities as an herbicide for carrots. However, supplementary tests with this oil showed its margin of safety to be entirely too small for practical use. Carrots were often killed at rates of application only slightly above those necessary to control weeds. Another unsatisfactory feature of this type of oil is the danger of flavors which is discussed later.

The 20 per cent emulsion of E-407 was the only material used in these two experiments other than Stoddard solvent that appeared to warrant further testing.

Experiment III:—This experiment was laid out as a 6 x 6 latin square except that each block was split, one-half receiving only one spray while the other half received two applications. Planting was done

May 22 on peat soil at Madison, Wisconsin and the first spray was applied on June 20 at which time the carrots had an average of about two true leaves. The carrots were 6 to 8 inches tall on July 6 when the second spray was applied. All applications were at the rate of 100 gallons per acre. Harvesting was done between October 13 and 18.

The results of this experiment are presented in Table II. Stoddard solvent, Oleum Spirits (a closely related material) and the mixture of

TABLE II—EFFECT OF SELECTIVE PETROLEUM WEED SPRAYS ON THE YIELD OF CARROTS IN EXPERIMENT III

Treatment	Observations on Weed Control†	Observed Injury to Carrots		Yield of Carrots (Tons Per Acre) 1½-Inch Min. Diam.	
		First Spray	Second Spray	Sprayed Once	Sprayed Twice
Stoddard solvent	Good	None	None	22.2	19.8
Oleum spirits	Good	None	None	21.3	22.8
E–407 (20 per cent)**	Fair to good	Severe	Moderate	13.4*	9.0*
Aromatic solvent (35 per cent)**	Poor	None	Slight	19.6	16.6
E–407 (10 per cent in No. 1 fuel oil)	Good	None	None	19.5	20.1
Check (hand weeded)	Good	None	None	20.2	21.0

*Difference compared to check significant at 1 per cent level. No other treatments significantly different from check.
**Emulsion of oil in water.
†Observations made only after first spray application. Too few weeds were present in most plots at time of second spray to obtain accurate notes.

10 per cent E–407 in No. 1 fuel oil all gave good control of weeds with no observed injury to the carrots and no reduction in yield. The last-mentioned spray would cost about one third less than the first two but has disadvantages from the standpoint of flavor as discussed later. There seemed to be little need for more than one spray since what few weeds remained after one application could be pulled more cheaply by hand.

The 20 per cent emulsion of E–407 was not quite as effective as a weed killer as the above-mentioned materials, yet caused severe injury to the carrots and a highly significant reduction in yield. The second spray resulted in additional injury, but the interaction of number of sprays X treatment was not significant.

These results are in contrast to those in Experiments I and II with the same emulsion. The greater amount of injury may be partly accounted for by the smaller size of carrots and smaller weed population in this experiment thus giving a greater concentration of spray on the carrot leaves. Supplementary tests using several aromatic solvents indicated that the margin of safety with all the emulsions used seemed to be much smaller than for Stoddard solvent. It was noted that droplets of the emulsion tended to form in depressions on the leaves and that injury occurred in these spots. The surface tension of the emulsions was apparently considerably greater than that of the straight oils used since droplets did not form to any extent with the latter materials. This apparent difference in surface tension seemed to be the best explanation for the poorer results with emulsions. Although these results are discouraging it is possible that by varying the kind or concentration of emulsifier, greater success might be obtained.

Results of Flavor Scoring

The carrots used for this work were obtained from the plots in Experiment III that were sprayed with Stoddard solvent, Oleum Spirits, 10 per cent E–407 in No. 1 fuel oil, and from the check plots. Samples were also taken from adjacent rows of the same planting which received special spray treatments. These special treatments consisted of a No. 1 fuel oil and Stoddard solvent applied on July 27 at which time the carrots had roots from ¼ to ½ inch in diameter. No. 1 fuel oil did not in itself give good control of weeds, but it was desired to determine its effect on flavor to see if it could be used as a base for mixtures with aromatic solvents.

To obtain samples for tests at an early bunching stage, a small but equal number of carrots were pulled at random from every plot and then combined by treatments. These samples were taken from the plots in Experiment III on August 15 while those from the special treatments were taken August 6, and in both cases they were judged the day after harvesting. These carrots were younger than they would ordinarily have been when harvested for bunching, the roots having a diameter of about ¾ to 1 inch. The following procedure was used in sampling at canning stage. After recording the yield, all carrots under 1½ inches in diameter and all those showing severe yellows infection, cracking, rots or other blemishes were discarded. From the remaining carrots in each plot, 25 were taken at random and were then combined by treatments and put in cold storage. At time of testing, random samples of 20 were taken from each lot for each day's scoring.

Preliminary Testing of Bunching Carrots:—In the preliminary testing of the flavor of bunching carrots, 16 advanced foods students did the scoring. They were asked to assign a numerical value from 0 to 10 and to describe any peculiar flavor which they noted. The samples were numbered and no indication was given as to the type of treatments which had been applied. The carrots were those in Experiment III which were sprayed either once or twice with Stoddard solvent, Oleum Spirits or 10 per cent E–407 in No. 1 fuel oil. While the scores were considerably lower for the treated than for the check or untreated carrots, the data are not sufficiently extensive or consistent to warrant a definite conclusion regarding bunching carrots given these treatments. It was observed, however, that the flavor varied from root to root and was not uniformly distributed in any one root. Also, it was found that the flavor of the petroleum products was not dispelled by cooking.

The carrots taken at bunching stage, 10 days after being given special treatments on July 27, were also scored for flavor. For those sprayed with No. 1 fuel oil, the average score was 2.7 and for those sprayed with Stoddard solvent, the score was 4.4. These were based on a scale of 0 to 10, the highest score representing excellent flavor. The descriptive terms which the scorers suggested are of interest. There was no doubt regarding the identification of the fuel oil flavor in these carrots, for every judge used one of the following terms: gasoline, kerosene, oil, axle-grease, fly or chemical spray. In contrast, the judges failed to identify so clearly the flavor of carrots treated with Stoddard

solvent as oily, only about 1/5 as many judges suggesting such terms. Instead, for these carrots the descriptions were often flat, strong, bitter and sometimes "cold-cream" or "soapy". There was much less uniformity in the descriptive terms used for Stoddard solvent than for fuel oil. It should be pointed out that this was an extreme test in that carrots were judged only 10 days after spraying.

Judging of Canning Carrots:—Carrots which were pulled in October at the canning stage were judged for flavor in two series, eight persons doing the scoring throughout. In Series I the untreated or check carrots and those given one or two sprays with Stoddard solvent in Experiment III were used. Length-wise sections each constituting one-fourth of the root were taken from 20 carrots and shredded, then thoroughly mixed to give as homogeneous a sample as possible. Duplicate samples of the untreated and of the two treated lots of carrots were scored on 4 days from 2 to 4 weeks after harvesting. The flavor scores are, therefore, the average of 64 tastings on each lot. The six samples (three lots in duplicate) were randomized and offered to the judges by number. The results are presented in Table III and showed that

TABLE III—THE EFFECT OF PETROLEUM SPRAYS ON FLAVOR OF CANNING CARROTS

Treatment	Date of Spraying	Flavor Score*
Series I		
None (check)		7.2
Stoddard solvent	June 20	7.3
Stoddard solvent	June 20 and July 6	7.5
Series II		
None (check)		7.7
Stoddard solvent	July 27	8.0
No. 1 fuel oil	July 27	4.8**

*Maximum possible score = 10.
**Difference compared to check significant at 1 per cent level. No other treatments in either series significantly different from their respective checks.

no statistically significant change in flavor of canning carrots was detected due to the spraying early in the summer with Stoddard solvent either once or twice. None of the judges suggested an oily flavor in any of these lots.

Included in Table III are the data of Series II which was a single day's scoring of carrots sprayed in midsummer in comparison to the untreated or check carrots. The treated carrots in this series were harvested October 13 from the rows given special treatment, that is, sprayed on July 27 with either Stoddard solvent or No. 1 fuel oil. The procedure and conditions of scoring were the same as for Series I except that each set of duplicates were randomized separately. Again, the judges did not consider the carrots sprayed with Stoddard solvent inferior to the untreated ones, but definitely rated undesirable the flavor of the carrots on which No. 1 fuel oil had been used.

The results of these two series on carrots sprayed either once or twice early in the summer or once in midsummer indicate no off-flavors in canning carrots treated with Stoddard solvent. Lachman

(4) and Grigsby (2) have also reported the lack of undesirable flavor in carrots treated with solvents of the Stoddard type under similar conditions. Since the flavor of carrots in our experiments had been considered undesirable when judged 10 days after spraying with Stoddard solvent as indicated in the preliminary work, there needs to be further study to determine the length of time that these flavors persist after spraying.

Certain conditions influencing the validity of flavor testing might be pointed out. The necessity of shredding representative sections of at least a moderate number of roots and thorough mixing to give a more homogeneous sample was evident from the variation in scores and from definite statements of the judges in the preliminary tests when the carrots were cut into small pieces. If there is no interfering factor, the inclusion of duplicates from the shredded mixed carrots in a lot permits an assessment of the scorer's ability to judge precisely. A definite bias was introduced in some of the tests due to taste fatigue. There was a tendency to consider the first carrots good and the last ones poor in flavor regardless of treatment. Thus in certain tests there was found a highly significant difference between the first of the duplicates and the second ones of the pairs. It is thus necessary to have each lot presented in each position the same number of times in the total scorings or to judge the lots arranged in random fashion on a sufficient number of days so that the averages will not be biased. The critical examination of the data and statistical methods of analysis of variance can be used to gauge the influence of some of these factors and to serve as a guide in the planning of further flavor scoring.

There are, thus, many pitfalls in the subjective scoring of flavor. Since no objective measure of flavor is available, efforts directed toward increasing the reliability of the scoring procedures are of great importance. Attention should be given to the preparation of a sample as representative and homogeneous as possible, to the evaluation of a scorer's ability to duplicate judgments and to the elimination of bias in so far as the plan of the judging can accomplish it. Then critical judgment and the use of statistical methods to segregate the variance due to measurable interfering factors are of great importance in the interpretation of flavor scores.

Summary

Several petroleum products available in Wisconsin were tested to determine their relative effectiveness as selective weed sprays for carrots and their influence on the yield and flavor. Of the materials tested, Stoddard solvent applied undiluted proved to be the most satisfactory from all standpoints. This product when used at the rate of 100 gallons per acre gave good control of all the annual weeds encountered with the exception of ragweed yet resulted in no apparent injury to the crop and no reduction in yield as compared to hand weeded carrots. Extensive flavor judgings showed carrots sprayed with Stoddard solvent and harvested at canning maturity to be free from any objectionable flavors due to the spray. On the other hand, our data do not warrant a definite conclusion as to the period of persistance of the Stod-

dard solvent flavors after spraying so there is a possibility of off-flavors in bunching carrots.

The kerosenes and No. 1 fuel oils sold in Wisconsin did not give good control of weeds while No. 3 fuel oil often resulted in considerable injury to carrots. Tests using carrots sprayed with No. 1 fuel oil showed that this material left an oily flavor under many conditions. Therefore, a mixture of 10 per cent E–407 (an aromatic solvent) with No. 1 fuel oil cannot be recommended even though it gave good weed control and no injury to the carrots. Emulsions of aromatic solvents in water often severely injured the crop at concentrations great enough to give good weed control and therefore were not satisfactory.

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The Value of Several Chemicals as Selective Herbicides for Vegetable Crops[1] (Preliminary Report)

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Recently there has been a great deal of interest in the use of selective sprays to control weeds in vegetable crops. Certain oils have given good results on carrots, parsnips and some other members of the Umbeliferae family and have been used extensively by vegetable growers in some areas (3, 4, 6, 9, 11). It has been reported that onions can be sprayed successfully with dilute sulfuric acid (1, 5, 7) although apparently less weeds are controlled than is the case with the oil sprays used on carrots. Westgate and Raynor (13) working in California obtained good results with Sinox (sodium dinitro-ortho-cresylate) on transplanted onions and later Raynor (8) reported its successful use as a selective weed spray on seedling onions. On the other hand, Grigsby and Barrons (5) and Newhall *et al* (7), reported considerable injury to onions sprayed with Sinox and found dilute sulfuric acid to be more satisfactory.

Sinox was suggested as a possible selective spray for peas by Westgate and Raynor (13) and more recently it has been recommended for use on this crop by Raynor (8) and Barrons and Grigsby (2). The latter authors also reported good results on peas with the ammonium salt of dinitro-ortho-secondary-butyl phenol.

Reference is made by Robbins, *et al* (10) to the use of a strong solution of sodium chloride as a selective spray for cranberries and solutions of common fertilizer salts for control of weeds in cereals. There seems to be no reference, however, to the use of these salts as selective sprays for vegetable crops. Recently, 2–4–dichlorophenoxyacetic acid has received a great deal of attention as an herbicide for the control of many kinds of weeds and as a selective weed spray for use on several crops belonging to the grass family. There appears to be very little published information on its possible use as a selective herbicide fot vegetable crops with the exception of a report by Barrons and Grigsby (2) that peas were severely injured by a 2,4–D spray.

The purpose of these experiments, which were conducted during the 1945 growing season, was to determine the relative value of several chemicals as selective weed sprays for vegetable crops.

Materials and Methods

The spray materials used and the sources of supply were as follows: Stoddard solvent from Sinclair Refining Company; Sinox from Standard Agricultural Chemicals, Inc.; the sodium salt of 2,4–dichlorophenoxyacetic acid and G–506 (ammonium salt of dinitro-ortho-secondary butyl phenol) from the Dow Chemical Company; sulfuric acid and several salts from other sources. The wetting agent used in some of the salt sprays was Triton B–1956 from Rohm and Haas Company.

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The vegetable crops and varieties used were as follows: carrots, Red Cored Chantenay; onions, Southport Yellow Globe; beets, Perfected Detroit; peas, Thomas-Laxton; cabbage, Wisconsin Hollander; lima beans, Henderson Bush. The weeds commonly encountered included the following: pigweed *(amaranthus retroflexus)*, lambs-quarters *(Chenopodium album)*, smartweed *(polygonum pennsylvanicum)*, purslane *(Portulaca oleracea)*, galinsoga *(Galinsoga cilita)*, foxtail *(Setaria spp.)* and crab-grass *(Digitaria spp.)*

Several plantings of the vegetables were made and these were mostly on peat soil. Spraying was done at various times throughout the season using a small hand sprayer and the rate of application was about 100 gallons per acre. The individual plots included from 5 to 20 feet of row and the number of replicates varied from 2 to 4 in the different experiments. Most spray treatments were repeated on several dates under various conditions and in every case they were repeated on at least two different dates. The stage of growth of the crops when sprayed was approximately as follows: Carrots, two to four true leaves; onions, one to two true leaves; beets, two to five true leaves; peas, 4 to 8 inches tall; cabbage, two to four true leaves; lima beans, four to five true leaves. The weeds were usually not over 4 inches tall at time of spraying.

Results

All the chemicals were given preliminary tests to determine the appropriate concentrations to use. In later experiments the lowest concentration of a material was used that seemed to give good control of the weeds that were susceptible to that particular material. The effect of the seven most extensively tested sprays on several vegetables and weeds is presented in Table I. The data presented in this table combine the results of a large number of experiments.

TABLE I—Effect of Some Selective Herbicides on Certain Vegetable Crops and Common Weeds

Crop or Weed	Relative Injury to Plants*						
	Stoddard Solvent	2,4-D 1:1000	Sinox 1:100**	G-506 1:200	H_2SO_4 3 Per Cent by Volume	NaCl, 25 Per Cent	NaCl 25 Per Cent Plus Wetter†
Crops							
Carrots	1	3	3	3	3	2	3
Onions	3	3	2	2	1	1	3
Beets	3	3	3	3	3	1	1
Peas	3	3	2	1	1	1	3
Cabbage	3	3	3	3	1	1	2
Lima beans	3	3	3	3	3	3	3
Weeds							
Pigweed	3	3	3	3	3	3	3
Smartweed	3	3	3	3	3	3	3
Galensoga	3	3	3	3	3	3	3
Lambs-quarters	3	3	3	3	1	1	1
Purslane	3	3	3	3	2	1	1
Foxtail and Crab-grass	3	1	1	1	1	1	3

*Injury to plants expressed numerically; 1—none to slight, 2—medium, 3—severe to killed.
**One gram of ammonium sulfate added to 400 milliliters of spray mixture as an activator.
†0.1 per cent of Triton B-1956 added to spray mixture as wetting agent.

It will be noted from Table I that Stoddard solvent killed or severely injured all vegetables and weeds on which it was sprayed with the exception of carrots. This material has proved to be highly successful as a selective spray for carrots as reported in detail elsewhere (12). All of the vegetables were killed or severely injured by 2,4-D as were all the weeds with the exception of the grasses. This chemical therefore offers little or no promise as a selective spray for the vegetables tested.

Sinox and G-506 are closely related chemicals and at the concentrations used they gave similar results. Both killed the weeds present with the exception of grasses. They also killed carrots, beets, cabbage and lima beans. On peas, G-506 gave only slight injury and appeared to have possibilities as a selective spray for this crop. Sinox at the concentrations used caused more damage to peas than did G-506. It is possible, however, that at a somewhat greater dilution or by omitting the activator Sinox would give comparable results. These results are in general agreement with those of Barrons and Grigsby (2). They reported good success on peas with G-506 at a concentration of 3 pints per 100 gallons. Sinox spray at 1 : 100 also gave good results in their experiments when the activator was omitted but caused considerable injury when 1 pound of ammonium sulfate per 100 gallons was added to the spray.

Onions were burned considerably and several plants usually killed by the Sinox and G-506 sprays. In supplementary experiments in which the concentrations of the sprays were varied, considerable injury to the onions always occurred when the concentration was high enough to give good control of weeds. Yield records were obtained on two experiments on peat soils each having four replications. The results are presented in Table II. Sinox sprays at 1 : 80 and 1 : 160 dilutions containing an activator caused large and highly significant reductions in the yield of onions at both locations. At location II, Sinox sprays resulted in a large number of "stiff-necks" or "bottle-necks". Neither Sinox nor G-506 appear to offer much promise as selective sprays for onions under Wisconsin conditions. These results are in agreement with those of Newhall *et al* (7) in New York and Grigsby and Barrons (5) in Michigan, but do not agree with those reported

TABLE II—The Effect of Certain Weed Sprays on the Yield of Onions

Treatment		Yield of Onions in Bushel Per Acre	
Material	Concentration	Location A	Location B
Sulfuric Acid	2 per cent*	169	881
Sulfuric Acid	3 per cent*	186	807
Sodium Chloride	25 per cent	210	797
Sinox	1:80**	113	500
Sinox	1:160**	165	516
Check (hand weeded)	———	238	894
Least difference for significance	5 per cent level	52	77
	1 per cent level	73	106

*By volume.
**One gram of ammonium sulfate added to 400 milliliters of spray mixture as an activator.

by Raynor (8) working in California. The greater success reported by Raynor may be due to the extremely different climatic conditions under which he worked.

As shown in Table I, dilute sulfuric acid was not as good a weed killer as the previously discussed materials. It did not kill lambs-quarters and grasses and was only moderately effective against purslane. This spray killed carrots, beets and lima beans, but caused only slight injury to onions, peas and cabbage. Because it did not control as many weeds as did G–506 and Sinox it offers less promise on peas than do these chemicals. It might have limited value on direct seeded cabbage, but this is of little importance. On onions, sulfuric acid was perhaps the best of the chemicals tested, but was still not very satisfactory. This is in agreement with the work of Grigsby and Barrons (5). In the yield experiments (Table II), a 3 per cent sulfuric acid spray resulted in a slight reduction in yield which is significant at the 5 per cent level. Its greatest disadvantages, however, lie in its poor control of certain weeds and in its highly corrosive nature which necessitates the use of special spray equipment.

A 25 per cent solution of sodium chloride (25 grams in 100 ml of total solution) caused only slight injury to onions, beets, peas and cabbage. Table II shows the effect of this spray on the yield of onions. There was a significant reduction in the yield at Location B when a salt spray was used, but not at Location A. Yield records taken on an experiment with beets showed no reduction in the yield of this crop when a salt spray was applied either once or twice. In killing power this spray was somewhat comparable to dilute sulfuric acid, but was less injurious to purslane. The lack of control of several common weeds would seem to limit the possible use of this spray to locations where susceptible weed species predominate.

The addition of a wetting agent to the sodium chloride spray increased its killing power as shown in Table I. This spray killed or severely damaged carrots, onions, peas and lima beans and caused considerable damage to cabbage. Beets, however, in extensive tests have shown only slight injury. This spray, in contrast to sodium chloride without a wetting agent, severely damaged or killed the grasses and seemed to be somewhat more effective on the other weeds. Sodium chloride with a wetting agent therefore seems to offer promise as a selective spray for use on beets.

One practical difficulty in the use of sprays containing 25 per cent sodium chloride is that of dissolving the salt in the sprayer. Considerable time and agitation is required. Because of this disadvantage, a search was begun for other salts which are more soluble or might be toxic at lower concentrations and still be selective on beets. The following salts have been tested in comparison with sodium chloride: sodium nitrate, sodium carbonate, potassium chloride, potassium nitrate, potassium carbonate, ammonium chloride, ammonium nitrate, ammonium sulfate, calcium chloride, calcium nitrate, sodium nitrite, and Ammate (ammonium sulfammate). Of these salts only sodium nitrate and potassium chloride appeared to be as satisfactory as sodium chloride. Potassium chloride offers no advantage since it is no more

soluble at normal temperatures than sodium chloride. Sodium nitrate, on the other hand, seemed to give nearly comparable results to sodium chloride when used at the same concentration and being more soluble might offer some advantages. The cost of sodium nitrate is higher, but this might be offset by its value as a fertilizer if the regular fertilizer program was adjusted accordingly.

The killing action of the salts successfully used as selective sprays on beets may be simply one of plasmolysis. Robbins, *et al* (10), lists several relatively non-toxic fertilizer salts as possible herbicides and states that these kill by plasmolysis when present in high concentration. It is interesting to note that sodium nitrite, Ammate, calcium chloride and calcium nitrate were highly toxic to beets and showed no selective action. All the ammonium salts were more toxic to beets and less selective than sodium and potassium salts containing the same anions.

In addition to the crops and weeds listed in Table I, limited tests were conducted with spinach and lettuce and with wild mustard (Brassica arvensis). These tests indicate that all of these plants are killed or severely injured by the sprays listed in the table, but more data is needed before definite conclusions can be drawn.

SUMMARY

The results of several experiments are reported in which studies were made to determine the relative value of the following materials as selective weed sprays for certain vegetable crops: Stoddard solvent, 2,4-dichlorophenoxyacetic acid, Sinox (sodium dinitro-ortho-cresylate), G-506 (ammonium salt of dinitro-ortho-secondary-butyl phenol), dilute sulfuric acid and a 25 per cent sodium chloride solution both with and without a wetting agent.

Stoddard solvent gave good results as a selective spray for carrots. G-506 and perhaps Sinox appeared to offer the greatest possibilities on peas. Dilute sulfuric acid gave better results than any of the other materials on onions, but was still not very satisfactory. Sodium chloride without a wetting agent caused only slight injury to onions, beets, peas and cabbage, but its possible use would be limited because it did not control several of the common weeds. Sprays containing 2,4-dichlorophenoxyacetic acid killed all of the vegetables to which they were applied.

Sodium chloride with a wetting agent was a better weed killer than without the wetter and looked promising as a selective spray for beets. Tests with several other salts on beets showed most of them to be unsatisfactory and of those used only sodium nitrate seemed to offer any possible advantages over sodium chloride.

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2, 4–D as a Spray to Weed Corn

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PRELIMINARY tests suggest that 2, 4–D (2, 4-dichlorophenoxyacetic acid) can be used as a selective spray to destroy dicotyledonous weeds in a corn field.

The 2, 4–D used in these tests was dissolved in Carbowax 1500 at the rate of 1 part of the acid to 5 parts of carbowax; this was dissolved in water. The 2, 4–D was at a concentration of 1000 ppm.

Five different tests were made. In the first test corn 8 to 10 inches high was sprayed. The prevalent weed was bindweed (*Convolvulus arvensis*). In a short time after the spraying was completed, there was a heavy rainstorm. This washed the spray residue off of the plants; consequently, many of the weeds sprayed last were not killed. A second spraying was necessary to kill these weeds. The two sprays together gave good control of the weeds, with no apparent injury to the corn.

For the second test; a field of corn which was just starting to show tassels was selected. One area was sprayed with 2, 4–D; a second area was sprayed with a water soluble preparation containing 70 per cent 2, 4–D, obtained from the Dow Chemical Company, used at 1000 ppm; and a third area was left unsprayed as a control. The two sprays gave good control of the weeds with only slight injury to the corn. No effort was made either to spray the corn or to avoid spraying it. The weeds killed were field mustard *(Brassica arvensis)*, pigweed *(Amaranthus)*, lamb's quarters *(Chenopodium)*, ragweed *(Ambrosia)* and burdock *(Arctium)*. A few corn plants in the sprayed plots were bent, as if in response to the growth promoting action of the 2, 4–D.

A third test was carried out in a field of corn which was starting to put forth tassels. 2, 4–D was used on the entire field; no control area was left. The major weed was purslane *(Portulaca)*. Every effort was made to keep the spray away from the upper half of the corn plants; the spray nozzles were kept within a foot of the ground at all times. The purslane was not killed, but its growth did seem to be stopped. There was no evidence of any injury to the corn.

A fourth test was made in a field of corn just starting to show tassels. 2, 4–D was used on three small plots in this field. A heavy application of spray was given to the corn plants; the spray nozzle was directed into the top of each corn plant. This spray was injurious to the corn. The plants bent over just above the ground, as if blown by a strong wind. The ears did not fill out well, and the kernels did not mature as quickly as those on the unsprayed corn. *It would not be safe to advise farmers to spray corn when the tassels have begun to appear.*

A fifth test, conducted at the same time as the fourth but on younger corn, showed less injury to the corn. Although the spray was directed into the top of each corn plant, yet there was only a little bending of the plants in response to the spray.

CONCLUSIONS

2, 4–D will kill many dicotyledonous weeds, or at least check their growth. It can injure large corn plants if sprayed directly into the tops of the plants. It is relatively harmless to young corn plants. This conclusion should be tested more extensively before the chemical is recommended to farmers as a selective weed spray for corn fields.

The Use of Oil Sprays as Selective Herbicides for Carrots and Parsnips II[1]

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THE decreasing number of hand laborers and the narrowing margins of profit in vegetable growing make necessary more effective methods of weed control than those formerly used, such as hand weeding and hand hoeing. In several publications (12, 13, 14, 15, 16) the author has described the use of "Stoddard Solvent," a naphthenic paint thinner and dry cleaning fluid, as a means of controlling weeds in fields of carrots and parsnips. More recently Sweet, *et al.* (22, 23, 24) have confirmed the validity of these findings.

The discovery and use of Stoddard Solvent as a selective herbicide has merely been an attempt to transfer a commercial practice in use on the Pacific Coast (6, 18) to our Eastern area. The material used for this purpose in California is known as stove oil, but oils with similar specifications are not available at present in the East; hence the search for suitable substitute compounds. The purpose of this report is to present the results of further work using Stoddard Solvent and other materials as weed killers in several vegetable crops.

MATERIALS AND METHODS

Stoddard Solvent from several oil companies, a number of other compounds, mixtures of compounds, and a few emulsions have been tested in the greenhouse and out-of-doors to determine their general usefulness as selective herbicides for members of the family Umbelliferae as well as some of the other vegetable crops. The various materials were applied with a Brown No. 4 hand sprayer fitted with a Monarch No. 059 flat-fan nozzle. The sprayer developed approximately 60 pounds pressure to the square inch and the materials were applied at the rate of approximately 125 gallons per acre. The weeds and crops were sprayed at various stages of development and each of the sprays was applied a number of times to serve as replicates. The weed population encountered in these tests was fairly representative of commercial field plantings and included the following sorts: crab, wire, or fall grass, purslane, galensoga, smartweed, chickweed, lamb's quarters, shepherd's purse, ragweed, and white, green, and common pigweeds. In addition to the specific crops in question, seeds of radish, spinach and domestic rye grass were sown in flats to serve the purpose

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of a weed population in the greenhouse tests. An abnormally heavy amount of rainfall, during the summer of 1945 kept the soil too wet for best plant growth throughout the growing season and the relative humidity of the air was also quite high for most of this period.

Results and Discussion

As early as 1919 (10) it was recognized that certain aromatic materials in petroleum were more toxic to plant growth than the other constituents. Crowley (9) was of the opinion that certain paraffinic kerosenes were more toxic than naphthenic (aromatic) kerosenes.

It has been rather definitely established, however, that carrots tolerate the aromatic (naphthenic) compounds of oil whereas most common weeds are killed by them (6, 18, 19). This is the basis for the differential killing of weeds in carrot fields. The various oils used in these experiments (Sovasol No. 5, Sun Spirits, Mineral Spirits, Varsol No. 2, Naphtha No. 52, Shell ACX No. 76) pass the specifications for Stoddard Solvent. They contained from 12 to 15 per cent of aromatic compounds, and, with the exception of Ragweed, killed all weeds encountered very satisfactorily.

The Nature of Oil Toxicity:—Stoddard Solvent promotes an acute toxicity, that is, "a rapid killing of all tissues with which the oil comes in contact." Acute toxicity is strictly a chemical effect (6) and the evidence at hand seems to indicate that oils injure the protoplasm of cells by altering the lipoid or fatty constituents (19). On the other hand, the resistance of young carrots to certain petroleum oils is probably entirely physiological because the leaves are wetted by the spray, which undoubtedly penetrates, yet they are not appreciably affected (19). Preliminary investigations indicate that the oil causes a very quick destruction of the chlorophyll of susceptible plants.

Effects of Environmental Factors:—Although it is reported that oils kill most rapidly in warm weather (19) no difficulty was encountered in killing weeds with Stoddard Solvent at temperatures as low as 45 to 48 degrees F. With the temperature at 90 degrees F and the sun shining, the weeds became quite wilted within 10 minutes after spraying. Under most conditions the weeds were dry and dead after 3 days had elapsed. Succulent carrot plants 2 inches tall, grown in the greenhouse at 80 to 85 degrees F were killed with Stoddard Solvent. Carrots grown in the greenhouse at 60 to 65 degrees F, however, showed no deleterious effects of the spray. Weeds that were sprayed during a prolonged rainy period did not succumb as quickly as those sprayed in warm sunny weather, but the final weed mortality was just as great. It is reported that oils are more toxic when the weeds are wet (22, 23). This in part indicates the complex nature of the selective effects of oil sprays. The entire weed population, even minute plants barely visible, were killed and young carrots received little or no check as is usually the case from the disturbance of their roots by hand weeding. When the weeds were sprayed properly they did not grow up from the base as do weeds that have their tops broken off in hand weeding.

Timing the Application:—Stoddard Solvent has been used on weeds in various stages of development from minute weeds that have barely germinated to and including some as large as 8 inches tall. With the largest weeds 200 to 300 pounds pressure may be necessary to insure greater penetration of the oil, or in some cases a second spray may be desirable to effect complete killing. Users of stove oil or kerosene must be cautioned against a second application since it is doubtful whether the oily flavor will be dissipated from the roots before they develop to a marketable size (3, 18). With weeds up to three inches tall, however, one application of oil at 100 pounds pressure has generally given satisfactory results. Beare (4), using kerosene, found that larger droplets of spray resulting from low pressure increased the degree of burning in carrots.

There has been some question as to when to spray carrots. To delay the spraying of weeds somewhat has the advantage of allowing a maximum number of weed seeds to germinate and thus a larger percentage of the weed population is killed. The optimum time for applying the spray, however, is when the weeds and crop plants are small. Young weeds are more easily killed and the crop is more apt to be benefited by early removal of weed competition. As a general rule, the older the weeds become, the harder they are to kill. This is especially true after they have developed a seed stalk. Weeds are more susceptible to the effects of the oil after several days of rainfall and other conditions that promote succulent growth.

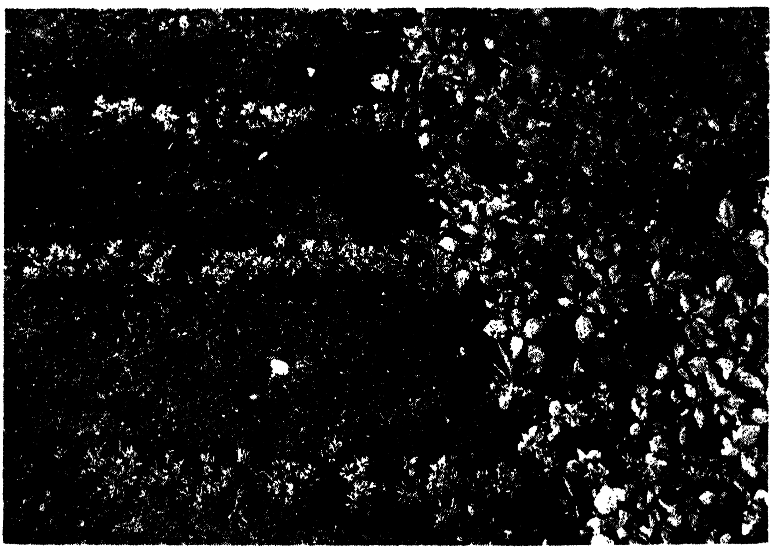

FIG. 1. *Left:* Showing complete weed control in a plot of carrots 1 week after spraying with Sovasol No. 5 (Stoddard Solvent). *Right:* Showing the unsprayed portion of the plot. The weed population was made up largely of galensoga, pigweed, crab grass and purslane. These plots received no cultivation or hand weeding.

Stoddard Solvent has given very satisfactory weed control in our tests and 35 farmers that were contacted and questioned reported that they sprayed 160 acres of carrots with complete weed control except for ragweed. With all weed competition removed it is likely that the ragweed population will build up rapidly unless this weed is promptly removed by hand weeding. Witch or quack grass *(Agropyron repens)* was killed back to the ground with a heavy application of the oil (200 gallons per acre) but sprouted up again in 2 or 3 weeks.

When carrots are sprayed with stove oil after the four-leaf stage, they may still have an oily taste and odor when harvested and spraying when only the cotyledons are present has in some cases thinned the stand (1, 18, 22, 23, 26). Carrots sprayed with kerosene before they have developed two true leaves suffered considerably from crop damage and if sprayed within 3 months of harvest retain a flavor of the oil (1, 5). In a test using Sovasol No. 5 (Stoddard Solvent) carrots planted May 24 were sprayed four times, June 23, July 13, August 7, and August 14. The roots did not taste of oil after they were cooked on September 9. From several tests it was evident that approximately 14 days were required to dissipate the flavor from well-grown roots that had been sprayed once with Sovasol No. 5. Carrots in the four-leaf stage sprayed with stove oil required an interim of 75 to 90 days between spraying and harvesting for the oily flavor to be dissipated from the roots (18).

The stand of either carrots or parsnips was not adversely affected when they were sprayed in the cotyledon stage but parsnips were generally severely damaged when sprayed after the plants attained a height of 6 inches. Carrots were sprayed in all stages of maturity but the tops were considerably burned and the core of the carrot damaged when they were sprayed after the root had attained a size of ½ inch in diameter during 1945.

A few farmers found that Stoddard Solvent was sufficiently volatile so that good control of weeds was not attained on hot (90 degrees F) sunny days where high pressures (300 pounds) were used and the spray was applied with regular potato sprayer nozzles carried about 2 feet from the weeds. The high degree of atomization coupled with quick vaporization probably accounts for the poor results. Where the weeds have been sprayed properly, the evidence indicates that weed control is effected most rapidly in warm weather.

In 1944 the use of Sovasol No. 5 caused a small percentage of carrot leaves to develop a lighter color (13). In some of the 1945 tests a marginal burning and browning of some leaves was evidenced. It was generally confined to one leaf per plant and this was invariably the oldest leaf on the plant. An analysis of the data showed that this condition occurred if and when the carrots were sprayed during periods of high humidity, particularly if the plants were wet from rain or heavy dew. Temperature, wind, sunshine, and soil moisture are intimately associated in this phenomenon, but in general the conditions that prevailed when the relative humidity was about 70 per cent or higher caused this damage. Carrots sprayed in the early morning were more susceptible to this damage than those sprayed later in the day.

Carrot plants that grew during a prolonged rainy period were also apt to show this mild degree of intolerance to the oil. The crown or growing point was not affected and reports from 35 vegetable growers stated that the marginal leaf injury did not reduce the crop yield or affect the time required to reach maturity.

Stoddard Solvent has a gravity of about 48.5 in °API units. This is noteworthy in view of the fact that Crafts (8) found when using stove oil, the gravity in °API units must be 38 or above because heavier oils, running as low as 34, produced severe crop injury. He also noted that oils which ordinarily did no damage to carrots became quite toxic and produced considerable crop damage after storage in closed containers for about a year.

FIG. 2. *Left:* Carrot plants 3 days after spraying with Sovasol No. 5 (Stoddard Solvent). *Right:* Carrots of the same age, 3 days after spraying with an emulsion composed of one part Edeleanu extract to three parts water. Many compounds that caused little or no crop damage when diluted with kerosene did considerable crop damage when emulsified with water.

When Stoddard Solvent was mixed with equal parts of paraffinic kerosene and sprayed on plots during periods when crop damage could be expected, the damage was reduced but at the expense of satisfactory weed control. Apparently an aromatic content of about 15 per cent is necessary to insure good weed control. Crop damage was somewhat increased when Stoddard Solvent was emulsified with water in equal parts, also at the expense of weed control.

In a few tests it was noted that some of the oils, particularly Sovasol No. 5, gave a slight response somewhat suggestive of a mild degree of epinasty of carrots in that the sprayed leaves cupped slightly upward and the petiole bent slightly downward.

Carrots sprayed with Stoddard Solvent required fewer cultivations

than was ordinarily considered necessary. Several farmers questioned the advisability of reducing the number of cultivations but the work of Thompson (25) indicates that fewer cultivations may even be desirable. Many times weeds may be sprayed and their control effected when it is too wet to cultivate.

Cases of increased yields have been reported after spraying with kerosene (1), although this has not been apparent after spraying with Stoddard Solvent.

Effects on the Soil:—Stoddard Solvent does not have a permanent effect on the soil. A good crop of beans was raised in 1945 on plots that were sprayed with the oil in 1944. Carrots were planted in mid-July, 1945, on plots that had been sprayed with Stoddard Solvent in early May and the carrots and weeds grew normally in every respect.

There does, however, appear to be a partial or short-time sterilizing effect on the soil after spraying with Stoddard Solvent from the standpoint of weed growth. The spray often prevents or retards weed seed germination for a period of 5 to 6 weeks. This effect was quite marked in 1944 (13) and was especially evident in 1945. Cole (5) has also noted a temporary or partial soil sterilizing effect following naphthenic kerosene sprays. When a new population of weed seed was brought to the surface by cultivation, however, germination and growth of weeds proceeded normally.

Effects of Various Oil Fractions:—Since Stoddard Solvent is a mixture of a great many compounds it was felt that some light would be shed on the active principle therein if certain factions of the oil were sprayed on weeds. Stoddard Solvent is a highly refined, straight-run petroleum naphtha with an initial boiling point of slightly over 148 degrees C, and a final boiling point of about 201 degrees C. Crafts and Reiber (6) have stated that, "evidently the fraction of petroleum which boils between 76.7 degrees and 218 degrees C is the highest in acute toxicity. The lighter fractions of gasoline are too volatile to be effective as herbicides; those of stove oil boiling above 218 degrees C are too heavy and exhibit chronic toxicity".

A sample of Gulf Stoddard Solvent was redistilled into five fractions having the following boiling ranges: 148 to 164, 164 to 173, 173 to 182, 182 to 191, and 191 to 201 degrees C. Each of these fractions was sprayed on small plots of carrots in need of weed control.

The three fractions having the lower boiling points worked about the same as Gulf Stoddard Solvent itself whereas the two fractions with the higher boiling points gave very poor weed control. Apparently a fraction boiling between 148 and 182 degrees C would be ideal for this work.

Effects on Various Crops:—A few tests were made on controlling weeds in celery seedbeds as well as celery growing in the field. Celery grown in the greenhouse at 45 to 50 degrees F was not damaged in the least by spray at the rate of 80 gallons per acre. Several lots of celery seedlings grown in coldframes during May were quite severely damaged when sprayed with Stoddard Solvent at 150 gallons per acre. Celery seedlings grown in outdoor seedbeds were not harmed by this spray.

Small celery seedlings grown out of doors and sprayed on July 21 were not affected by an application of 100 gallons per acre. Celery sprayed at the rate of 100 gallons per acre on July 30, one week after it was transplanted in the field, showed no ill effects from the spray. When sprayed one week later, however, the celery was very badly damaged with an application of 150 gallons per acre. Practically every plant that was sprayed in this test had the growing point or heart severely burned and eventually rotted. Large, well-grown celery was sprayed on October 8 at rates varying from 50 to 250 gallons per acre. Damage resulted from all rates exceeding 80 gallons per acre. It was felt that the hollow or groove on the inner side of the celery petiole was instrumental in directing the oil down to the heart of the plant where too great a concentration of oil was particularly toxic, and it was rather apparent that applications exceeding 80 gallons per acre caused crop damage in proportion to the amount of oil applied.

FIG. 3. *Left:* Celery 5 days after spraying with Stoddard Solvent at the rate of 150 gallons per acre. *Right:* Control. Note that the heart of the treated plant has turned very dark. Later this portion of the plant rotted out completely and adventitious branches sprouted out from the base of the plant. The plants were often very similar in appearance to those affected with "Blackheart," a physiological disease of celery.

Parsley was tolerant to the spray for the most part, but in several tests a considerable amount of marginal burn was evidenced, particularly when the spray was applied during very humid weather. Parsley did not seem to be any more sensitive in the cotyledon stage than in later stages of development. Dill, fennel, coriander, caraway, parsnip rooted parsley, and celeriac are other crops which resist these sprays.

Beets, cabbages, peppers, onions, young asparagus seedlings, as-

paragus during the cutting season, spinach, lettuce and turnip plants were all very severely injured or were killed outright by the spray. One vegetable grower sprayed around the base of the plants in an asparagus bed after the cutting season for the control of weeds with good results. However, the base of most of the asparagus plants was badly burned and the top growth of many plants appeared to be severely damaged. Another grower fitted a field and planted spinach and onions several days later. Just as the germinating seed was cracking the ground he sprayed with Stoddard Solvent. This treatment effected perfect weed control and obviated any necessity for cultivation. The crops were normal in every respect. This offers possibilities with other oil susceptible crops.

Stoddard Solvent was also used successfully to kill annual weed growth in the walks and around borders of a few Victory Gardens but death resulted where crop plants other than carrots or parsnips were hit by the spray.

Relative Cost:—The relative cost of using Stoddard Solvent as a means of weed control in comparison to hand weeding was also investigated. Most large carrot growers found that it cost about 45 dollars per acre for one hand weeding during 1945, whereas the use of Stoddard Solvent Spray cost from 16 to 19 dollars per acre. Vegetable growers were unanimous in their decision that the oil was superior to hand weeding in so far as results were concerned. The speed of the operation was a matter of the type of equipment used. Some growers using a knapsack sprayer easily covered one acre per day. Another grower using a large potato sprayer covered two acres in 20 minutes. Power sprayers generally distributed the oil more uniformly than a hand sprayer and somewhat lighter applications were therefore possible with a power rig.

It was found that severe skin irritation and blistering resulted from prolonged contact with Stoddard Solvent or clothing that was soaked from it. The clothing was rendered harmless as soon as the oil evaporated.

The Use of Other Compounds and Emulsions:—Rossini (20) has made rather extensive studies to determine which hydrocarbons are present in petroleum. A number of these compounds, particularly those that had a boiling point within the range characterized by Stoddard Solvent, were emulsified with water. These were also mixed with paraffinic kerosene at varying dilutions and compared with Stoddard Solvent to determine their relative capacities as selective weed killers in carrot fields. These tests were replicated twice during August and early September.

Some of the aromatics tested were diethylbenzene (meta and para mixture), pseudo cumene, cumene, ethylbenzene, para cymene, secondary amylbenzene, n-amylbenzene, para xylene, and tetralin. All of these compounds gave good, clear-cut weed control with no readily apparent crop damage when diluted with paraffinic kerosene to a strength of 15 per cent by volume. The weed killing action was much slower (chronic action) than that caused by Stoddard Solvent (acute action). Crafts and Reiber (6) state that chronic toxicity is a charac-

teristic of all oil fractions having a boiling range above that of ordinary gasoline. Carrot plants sprayed with these mixtures showed no burning or browning of plant tissues but they appeared to be somewhat stunted or dwarfed as compared to plants in hand-weeded plots or those sprayed with Stoddard Solvent. These compounds were also emulsified with water to a strength of 15 per cent by volume using 2 per cent of Triton B1956 as the emulsifying agent. The emulsions were generally unsatisfactory since they did a poor job of controlling weeds and most of them caused a considerable amount of crop damage in the form of leaf browning or burning. Many times complete death and often extreme stunting or dwarfing resulted.

Crafts and Reiber (6) have stated that Edeleanu extract, a by-product of the refining of kerosene, will kill weeds when diluted with three parts of kerosene or emulsified with three parts of water. Solvesso 3, and Shell ACX41 are both Edeleanu extracts and when mixed with kerosene gave very good selective weed control. When emulsified with water, however, using Triton X-200 and also Triton B1956 as emulsifying agents the results were not satisfactory. The water emulsions often caused considerable crop damage and weed control was not as prompt or complete as was deemed desirable.

Tidewater kerosene distillate and certain naphthenic kerosenes applied without dilution proved to have excellent weed killing properties and were highly selective for carrots. These oils were slower acting than Stoddard Solvent and although no test was made, it is suspected that the oily taste remained in the carrot roots considerably longer than did Stoddard Solvent. Paraffinic kerosenes were of little value due to their poor weed killing properties.

High flash naphtha diluted one to five, Sovasol No. 74 diluted one to four, and Avon weed killer diluted one to four with paraffinic kerosene all gave clear-cut weed control with good selectivity but were rather slow in action. Sovasol No. 75, a catalytically processed, high solvent naphtha has been found to be a good selective herbicide for carrots when diluted with two parts kerosene (13) and results from the present investigations confirmed the previous report. Sovasol No. 75 emulsified with water using Triton X–200 and Triton B1956 as emulsifiers was not satisfactory, however, due to a considerable amount of crop damage.

A mixture of 5 to 10 per cent of steam distilled turpentine in kerosene gave a reaction on the plants similar to that resulting from Stoddard Solvent in the greenhouse but this could not be duplicated in tests out-of-doors. Limonene, dipentene and pinene are the principal components of turpentine, but these offered little promise since they did not effect good weed control when mixed with kerosene or emulsified with water.

Members of the family Umbelliferae are a rich, natural source of aromatics and a number of the compounds they contain have been identified, isolated, synthesized and are available in reasonable quantities. It was felt that some one or more of these aromatics might be toxic to other plants and that Umbelliferous crops might tolerate them because they already contain appreciable quantities. Of the various

compounds tested, *viz.*, anethole, sodium anisate, sodium umbelliferone, anisic acid, anisaldehyde, anisole and anisidine, only anethole gave very promising results. Anethole used at 5 per cent strength and diluted with kerosene provided a good selective weed killer for carrots. When emulsified with water, however, using Triton B1956 as the emulsifying agent, good weed control was not effected and a considerable amount of crop damage resulted.

During the later development of the carrot crop it became clearly evident that none of the treatments described here were as effective or quick acting as various types of Stoddard Solvent with the possible exception of the Sovasol No. 75 kerosene mixture and this was especially true of the emulsions. "Oils are low in surface tension, seep down the stems and creep into crevices and protected regions where they come in contact with buds and meristematic tissues. Emulsions rapidly kill all tissues that are thoroughly wet, but they do not seep down into the crowns of grasses that may be below the soil surface" (7).

Carrot plants in plots sprayed with Stoddard Solvent invariably were further developed and the results were more uniform under a variety of conditions than with any other treatment. As Robbins *et al.* (19) have stated, "a given rate of application of a chemical does not give the same degree of control of weeds in every case." This depends on factors such as the type of weeds, their size and age, and the conditions prevalent during weed growth.

Summary

Extensive tests have shown that "Stoddard Solvent" is valuable as a weed killer in fields of carrots and parsnips. Other Umbelliferous crops that are resistant to this oil in the seedling stages are parsley, celery, dill, fennel, coriander, caraway, parsnip rooted parsley, and celeriac. Some of these plants, particularly celery, are damaged by the spray in their later stages of development. A scorching or burning of the older leaves often occurs if the crops are sprayed while wet from rain or a heavy dew. A number of other oils and aromatic compounds were found to be good selective weedicides when their aromatic content was adjusted at 12 to 15 per cent with kerosene but none were as effective or quick-acting as the various types of Stoddard Solvent. Anethole, an aromatic compound common to members of the family Umbelliferae, was selective for carrots and killed weeds at a strength of 5 per cent using kerosene as the diluent.

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The Use of 2,4–D as a Selective Herbicide in the Tropics, with Special Reference to the Culture of Sugar Cane

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IN THE tropics even more than in regions of middle latitudes, weed control is a pressing problem. In the hot and humid atmosphere, weeds, when left unchecked, may completely smother young crop plants within a few weeks. Dense, almost pure stands of certain species of weeds may be seen in the sugar-cane fields of Puerto Rico. For this no effective means of control is practiced. Two weed species in particular are notorious in this respect.

In moist lands the day flower (*Commelina longicaulis* Jacq. and *C. elegans* H. B. K.), locally known as *cohitre*, is the predominant weed. Control by hand hoeing is nearly hopeless because in the process its brittle stems are broken up into many pieces, each of which may readily give rise to a new plant. The shade provided by the cane and the moisture within the mulch of cane trash especially favor the quick reestablishment of commelina.

In fertile, better drained areas nutgrass (*Cyperus rotundus* L.), locally known as *coqui*, is the predominant weed. In fields of young "plant cane" this weed may be seen to cover the soil in dense stands which resemble a lawn. Hand hoeing actually aids in its propagation rather than checking its growth, because the hoe rarely reaches the plant's deeply buried growing point. On the other hand this cultivating practice leaves the coqui without the competition of other weeds.

A solution of these weed control problems lies in the use of 2,4–dichlorophenoxyacetic acid (2,4–D). Statistical analyses showed that this chemical is entirely harmless to sugar-cane plants. On the other hand, in relatively low concentrations, it causes complete extermination of commelina, nutgrass, and most other nongramineous sugar-cane weeds. As far as we are aware, this is the first time that a selective herbicide is reported which is completely effective against nutgrass.

METHODS

As soon as 2,4–D became available[1] in large enough quantities, field trials were begun. Preliminary experiments were carried out on the grounds of the Institute (1). Later more extensive trials were conducted in the sugar-cane fields of the Eureka Central[2]. When these were found satisfactory, 10 acres of plant cane infested with nutgrass

[1]We are indebted to the Dow Chemical Company for samples of 2,4–D and A–510. The latter is a soluble commercial weedkiller containing as its active principle 70 per cent of 2,4–D. Only 2,4–D converted into its ammonium salt was used in the experiments reported here. Parallel tests with A–510 showed that its lethal effect on weeds is not less than that of pure 2,4–D when compared on the basis of equal quantities of 2,4–D. Small quantities of 2,4–D were also obtained from the American Chemical Paint Company, and larger quantities from Eastman-Kodak Company.

[2]We are indebted to Mr. M. O. Proverbs, Manager of Cultivation of Central Eureka, Hormigueros, P. R. for his wholehearted cooperation.

and 5 acres of ratoon cane infested with commelina were treated by the Central in the summer of 1945. The results obtained here were in complete agreement with those obtained from trials run on a smaller scale.

Aqueous solutions of 2,4–D were easily obtained by converting the acid into its more soluble ammonium salt. This was done by dissolving 150 grams of 2,4–D into 4 liters of water to which 100 cc of a 28 per cent solution of ammonium hydroxide were added. By using an electric stirrer and warm water these stock solutions were made in a few minutes. In the field appropriate dilutions were made (for example 1 to 50 for an .075 per cent solution.) No spreaders were used in those experiments.

The final solutions were applied by means of a Myers bucket pump, with a Vermorel nozzle. This pump generated a pressure of about 200 pounds and produced a fine mist spray. It was found highly effective and convenient for our work. Knapsack sprayers were also used with success. "Coarse" sprays were found unsatisfactory.

Just enough spray was applied to wet the foliage of the weeds. The amount required per acre ranged from as little as 35 gallons per acre for commelina emerging from below the trash mulch of recently harvested ratoon cane to 250 gallons for densely growing nutgrass. As a rule only a single application was given. This was made at a time when the foliage was dry and no rain was expected for a 24 hour period following treatment. The weeds were treated before they had reached maturity.

In order to arrive at figures expressing the effectiveness of the sprays, counts of the number of nutgrass plants were made in permanent quadrats (2) of 4 square feet which were scattered throughout the plots. An initial count was obtained immediately after treatment and additional counts following 2, 3 or more weeks later. For commelina, estimates of the relative area covered by live plants were made, since the growth habit of this plant precludes the counting of individual plants.

Results

By treating the weeds with a variety of concentrations, curves showing the sensitivity of a specific weed to 2,4–D were obtained. Fig. 1 shows that a concentration between .05 and .075 per cent is sufficient to exterminate commelina completely. This herbicidal effect takes place slowly, about 2 weeks being required with commelina.

For the control of nutgrass .15 per cent 2,4–D or higher concentrations are necessary. Extensive field trials have shown that .15 per cent solutions eradicate about 85 per cent of this weed (Fig. 1), and provides sufficient control in practice. Smaller test plots demonstrated that .3 per cent gave complete eradication, without causing any visible damage to the cane plants. The killing of nutgrass is due to the destruction of the meristematic regions below the ground (Fig. 2). It is probable, in view of our knowledge with growth-regulating substances in general, that the 2,4–D is translocated downward to the region affected. About 3 weeks are required to complete the destruction of nutgrass.

The transmission of the effect of 2,4–D away from the point of application was also shown by a special experiment in which a single leaf

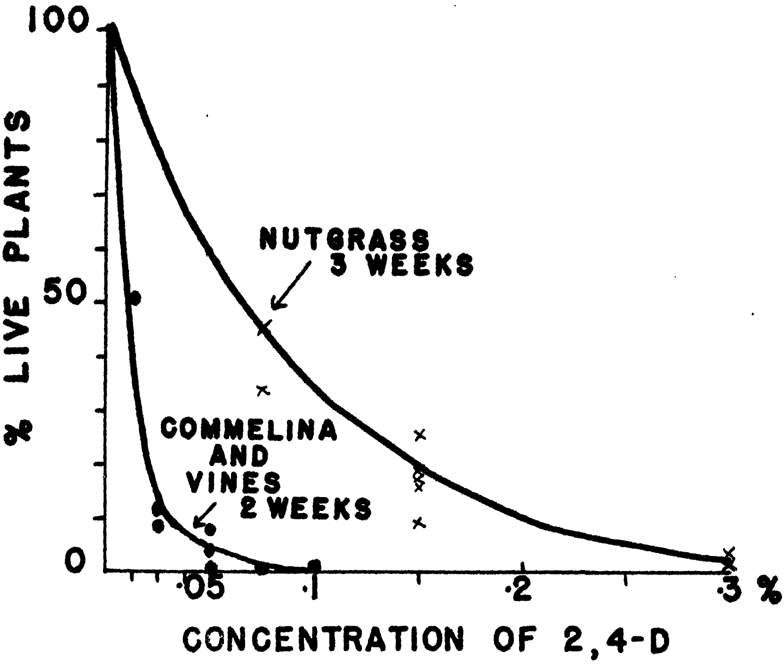

FIG. 1.

of shoots of commelina was painted with an .1 per cent solution in 50 per cent alcohol. After 2 weeks a stem region 10 cm below (basipetal) the treated leaf was dead, while the stem above (acropetal) this leaf was not affected. Similar tests with naphthaleneacetic, indolebutyric and indoleacetic acids in .1 per cent solutions did not show any killing of commelina stems.

In addition to commelina and nutgrass there are a number of other non-gramineous weeds which occur in cane fields. Among these are vines such as *Ipomoea polyanthes* R. & S., *I. tiliacea* (Wild.) Choisy, *I. rubra* (Vahl) Millsp. and *Stizolobium pruritum* (W) Piper. The ipomea vines, known locally as *bejuco de puerco,* are of the tree strangler type. The stizolobium vine is a legume, locally known as *pica pica.* Its presence in cane fields is undesirable because the stinging hairs of its pods injure workers. All of these vines appear to have a sensitivity curve closely resembling that of commelina, and therefore are easily eradicated by concentrations of .075 per cent 2,4-D. Although *pica pica* is an easily eradicated leguminous plant, several other legumes are quite insensitive to 2,4-D. Preliminary data show that woody legumes such as *Erythrina Berteroana Urban,* a widely used shade tree, *Mimosa pudica* L., and *Aeschynomene sensitiva* Sw. are not easily damaged by 2,4-D sprays.

The cost of the chemical used in a given weed eradication program depends upon the amount of solution and the concentration of 2,4-D necessary to effect killing. It will range from 50 cents per acre for a

field lightly infested with commelina or vines to 7 dollars for an acre heavily infested with nutgrass.[3]

Discussion

Weed control is an agricultural problem involving both physiology and ecology. The fact that complete eradication of nutgrass is possible at present in such a spectacular manner does not necessarily mean the end of the weed control problem. Neither does it mean that 2,4-D sprays will replace mechanical means of controlling weeds.

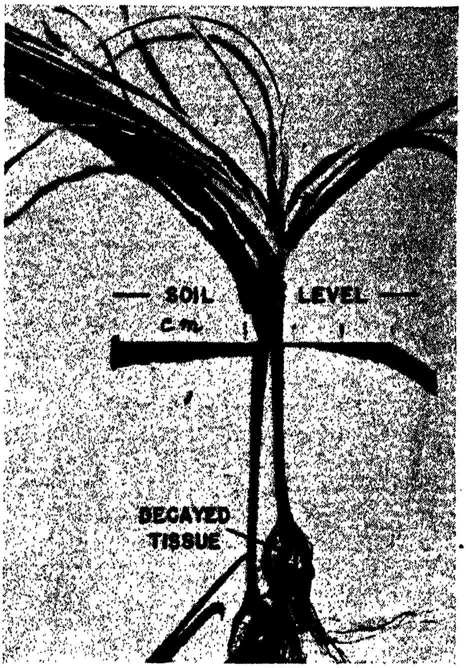

FIG. 2. Nutgrass *(Cyperus rotundus)* 1 month after spraying with 2,4-D. The meristematic region at the base of the pseudo-stem has deteriorated before the leaves show evidence of serious damage.

The very fact that 2,4-D is such an effective *selective* herbicide, in that it is not harmful to cane itself, carries with it a potential danger, for, as soon as the weeds susceptible to 2,4-D have been eradicated, non-susceptible ones will take their place.[4] Naturally the latter include grasses. However, most of these are effectively eradicated by means of the present hand-hoeing practice.

One may well ask why it is that weeds such as *cohitre* and nutgrass occur in cane fields in practically pure stands. In our opinion the answer to this question lies in the present method of mechanical cultivation (hand hoeing) now practiced in Puerto Rico. By this method most other weeds are eradicated except commelina or nutgrass. This practice leaves these weeds without the competition from other weeds which they would have encountered in a non-cultivated field. This results in an almost pure stand of *cohitre* or nutgrass in hand hoed cane fields.

With this in mind, it will be clear that a well balanced program of weed control should involve mechanical cultivation as well as spraying

[3]Computed on the basis of $4.40 per kg 2,4-D (Eastman-Kodak Company).

[4]In fields where treatments against commelina were given when the sugar-cane (ratoon) was already about 3 feet high, the soil between the cane remained practically free from weeds. In this instance no succession of weeds could take place because the dense stand of the cane shaded the soil so much that potential succession weeds could not grow for lack of light.

with 2,4–D. In our opinion the use of 2,4–D as a selective herbicide in sugar cane culture will correct the shortcomings of the mechanical methods of weed control, rather than supplant the latter entirely.

Summary

In the sugar-cane fields of Puerto Rico nutgrass or *coqui (Cyperus rotundus* L.) in some localities, and day flower or *cohitre (Commelina longicaulis* Jacq.) in others, occur in dense, almost pure stands. The present practice of hand hoeing is not only entirely ineffective against these weeds, but it is the direct cause of their prominence.

2,4–dichlorophenoxyacetic acid (2,4–D) has been shown to be a highly effective herbicide against these sugar-cane weeds. A single application of a .075 per cent aqueous solution eradicated commelina completely, while .3 per cent produced a similar effect upon nutgrass (Fig. 1). These concentrations were entirely harmless to sugar cane plants. In practice these concentrations can be reduced by one-half for satisfactory results. Certain vines occurring in cane fields are as easily eradicated as commelina.

After weeds susceptible to 2,4–D sprays have been exterminated, their place is usually taken by non-susceptible weeds. Prominent among the latter are grasses. Since these are controlled by the present hand-hoe method, it is recommended that an effective weed control program for sugar-cane fields consists of the combined use of mechanical and chemical (2,4–D) methods. The function of 2,4–D sprays, under the conditions discussed above, is to correct the shortcomings of the present practice of mechanical weed control rather than to supplant it entirely.

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2,4–Dichlorophenoxyacetic Acid Reduces Germination of Grass Seed

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On May 25, 1945, 100 plots 10 x 10 feet were laid out in a regular pattern so that each treated plot bordered on at least one untreated plot. The area was known to have a large population of dandelions, narrow-leaved plantain, wild white clover, black medick, yarrow and frequently crabgrass.

The grass was cut once a week. None of the clippings were removed or raked off. The northern section of the plot was primarily bent grass though the southern half was largely Kentucky bluegrass. Six treatments were made and there were six plots of each treatment. Thirty-four untreated plots were examined in the spring and again in September. Notes were also made at intervals during the summer. Notes were made on the basis of the number of plants per square foot of dandelions, plantain, clover, crabgrass and in certain instances other weeds as they occurred in colonies.

Dandelion (Taraxacum officinale):—Counts in the spring of 1945 indicated a range of from three to 100 plants of dandelion per square foot in the check plots. Similar count made in September 1945 indicated an average of three dandelions per square foot over the area. Counts ranged from as few as five dandelions to a plot of 100 square feet up to as many as 20 dandelions per square foot.

Narrow-leaved Plantain (Plantago lanceolata):—Infestation of this weed amounted to 5 plants per square foot for the check plots during May 1945. Count for September averaged 11 plants per square foot in the check plots.

Wild White Clover (Trifolium repens):—Counts were not made of the number of plants per square foot in this case but an estimate was made indicating whether the colony was light, medium or whether the plants were abundant throughout the area. When only 5 plants or fewer could be found in the entire plot, clover was listed as present only.

Crabgrass (Digitaria sanguinalis):—The summer of 1945 was especially favorable for the growth of lawn grasses. In general, there was little infestation of crabgrass. In 19 of the check plots, there were 5 plants or less of crabgrass per plot in September. Three plots had from 5 to 10 plants of crabgrass per plot, nine plots had less than 5 plants per square foot while the other two had from 5 to 10 plants per square foot.

Treatments

2,4–Dichlorophenoxyacetic Acid:—(2,4–D) used at the rate of 1000 ppm ½ gallon of solution for each 100 square feet (following Hamner and Tukey). Commercial forms of 2,4–D were applied according to concentration and rate as given by the manufacturer.

Ammonium Sulfamate:—This was used at the rate of 11 grams to the half gallon solution for each 100 square feet. Only one application of ammonium sulfamate was made.

Sodium Arsenite:—This was applied at the rate of 10 grams to the pint of solution to cover 100 square feet. A single application was made.

Sodium Chlorate:—This was used at the rate of 1½ ounces in 1 gallon of water applied to 100 square feet. A single application was made.

Ammonium Sulfate:—One pound was used for each 100 square feet. This was mixed with 2 pounds of sand and spread dry over the surface. Applications were repeated to the total of three for the season.

Cyanamid (granular):—Used at the rate of 1½ pounds per 100 square feet, 3 applications made throughout the season.

Results

Immediate Results:—All materials except 2,4–D discolored both the grass and the weeds. Where 2,4–D was applied the weeds were distorted but not unsightly. Late August application of ammonium sulfate and also cyanamid made during a dry spell caused some burning of the turf.

Results after 30 days:—Good control of weeds was obtained by treatments of 2,4–D, ammonium sulfamate and sodium arsenite. Ninety per cent and more of the weeds in these plots were dead and the grass had recovered.

Poor weed control resulted from the use of sodium chlorate, ammonium sulfate and cyanamid. Both weeds and grass recovered from initial discoloration, though with the fertilizers turf was scarred in some cases.

Re-Infestation by Weeds:—Six weeks after applying the treatments all except 2,4–D plots contained sizeable weed populations, including clover, dandelion and plantain. The use of ammonium sulfate and of cyanamid had increased the growth of the grass so that the proportion of grass to weeds in these plots increased throughout the season.

Crabgrass (Digitaria sanguinalis):—Heavy infestations of this weed were found only where the turf was badly injured from the use of the weed killer. This occurred with sodium chlorate and to a lesser extent with ammonium sulfamate.

Growth of crabgrass was consistently low in the sodium arsenite and in the 2,4–D plots treated in May. Even though bare areas existed in these plots they were free from crabgrass throughout the summer.

Summer and Fall Applications of 2,4–D Dichlorophenoxyacetic Acid

June 24 Applications:—Twelve plots were treated with 2,4–D or with one of its commercial forms. Satisfactory control of dandelion and plantain was obtained within 30 days. There was less injury to clover.

Eight of the 12 plots to which 2,4–D was applied in June were also fertilized at that time using ammonium sulfate, 1 pound per plot of 100 square feet. The fertilizer and the 2,4–D were applied the

TABLE I—INFLUENCE OF WEED KILLERS ON THE GROWTH OF GRASS AND OF WEEDS

Treatment May 25	Plots	7 Days May 30	30 Days June 24	Young Weeds Present August 16	Crabgrass	September Rating	
						Weed Control	Condition of Grass
2,4-D	6	Weeds curled	90 per cent kill	Few	Less than two plants/plot	2—good 4—excellent	6—good
Ammonium sulfamate	6	Grass and weed injury	90 per cent +kill grass rec.	Definite invasion	Heavy in patches	3—good 3—fair	4—good 2—fair
Arsenite	6	Grass and weeds burned	90 per cent kill grass rec.	Light invasion only	Less than two plants/plot	2—excellent 2—good 2—fair	6—good
Chlorate	6	Grass and weeds burned	Recovery of both grass and weeds	Heavy weed population	Abundant in scars ten plants/foot	6—poor	6—poor
$(NH_4)SO_4$	6	Light injury	Both grass and weeds recovered	Definite reduction of clover and later of weeds	Less than two plants/plot	3—excellent 3—good	6—excellent
Cyanamid	6	Light injury	Both grass and weeds	Reduced population of weeds and clover	Less than two plants/plot	2—excellent 2—good 2—fair	6—excellent

same day. At the end of 30 days, satisfactory weed control had been obtained and the grass was definitely stimulated by the application of the fertilizer. In September all of these plots were rated as excellent, both in weed control and condition of the turf. Crabgrass was present in September in only three of the 12 plots.

July 24 Application:—Sixteen plots in four series of four plots each were treated with 2,4–D. Each series contained one application of 250 ppm solution, one of a 500 ppm, one of a 1000 ppm, and one of a 2000 ppm solution at ½ gallon to 100 square feet.

Excellent control of dandelion and plaintain was obtained except where application was made with the 250 ppm solution of 2,4–D. In one series two applications were made a day apart. In this case, satisfactory control of dandelion and plantain was obtained even with the 250 ppm solution. No injury to the grass was observed even with the 2000 ppm solution repeated within 24 hours. Injury to wild white clover from application of 2,4–D was less in the July application than with the June or May application of this material. Crabgrass was present in both the checks and also in the 2,4–D treated plots. There was no reduction in the crabgrass with the July application.

August 23 Application:—Satisfactory control of dandelion and of plantain was obtained on 9 plots treated with 2,4–D, 1000 ppm, ½ gallon per 100 square feet in August. The use of fertilizer together with the 2,4–D improved the turf as it had done with the June and July application. The use of Sinox and 2,4–D in the same container applied at the same time gave immediate injury to the grass but it did not apparently interfere with the action of the 2,4–D on the dandelion and plaintain. This was also true of ammonium sulfamate.

September Application:—Ten plots were sprayed September 1 with four commercial fofmulations of 2,4–D as well as with 2,4–D-Carbowax preparation, used at the rate of 1000 ppm, ½ gallon per 100 square feet. On the first of October excellent results were obtained in the control of plantain and dandelion. Less clover was killed than in earlier applications. Between September 5 and 10, 5 acres of turf were sprayed with 2,4–D solutions at the rate of 500 to 1000 ppm using 300 gallons to the acre. The solution was delivered with a power sprayer at 300 pounds pressure and good results were obtained in the control of dandelion and of plantain on these larger areas. Wind blew the spray for some distance beyond the border for the plots and it was observed that dandelions were killed for a distancee of 30 to 50 feet from the point of application. Plaintain, both narrow-leaved and broad-leaved was killed for a somewhat greater distance from the point of application. Uniformity of application is necessary for uniform results.

Late September appplications of 15 commercial formulations of 2,4–D were used at the rates indicated by the manufacturers. Good control of dandelion and plantain was obtained. Reaction by clover was less than that previously (May) described. On the first of November many of the weeds were still green and apparently alive and in active growth. March 1, 1946, the dandelion and plantain had died during the winter leaving typical bare spots.

All the commercial formulations were applied in triplicate. A few formulations are slower in producing a reaction but the weeds under observation all reacted. Sodium arsenite and ammonium sulfamate also proved to be effective weed killers when applied in September.

INFLUENCE OF 2,4–DICHLOROPHENOXYACETIC ACID ON THE STAND OF LAWN GRASSES

Five-inch seed pans were used and the seed was planted and covered before an application of the appropriate amount of 2,4–D was applied. Chewings fescue, Kentucky bluegrass and Colonial bent grass were used in these tests. The first plantings were made July 25. Four pots of each grass was used in each test. The following tests were made:

The 2,4–D applied at the time of planting; second, applied when the seedlings had reached ¼ to ½ inch in height, in this case August 2; third, when the seedlings were 1 inch in height; and fourth, after the period of first mowing, that is, when the grass had reached a height of 2 inches it was first cut.

RESULTS

When the soil was sprayed at the time of planting, the stand of grass was reduced by approximately 30 per cent in the case of bent grass, 10 per cent with Kentucky bluegrass, and to a lesser extent with Chewings fescue.

Grass seedlings ½ inch in height showed some curvature after treatment with 2,4–D but later grew well. Grass seedlings 1 inch or more in height did not show any curvature except in the case of bent grass and then only a slight curvature followed by normal growth. Grass seedlings sprayed after the first cutting did not respond to 2,4–D spray beyond normal reaction of mature grass to this treatment. Tests were continued to determine the reaction of germinating grass to applications of 2,4–D 1000 ppm ½ gallon to 100 square feet. Six tests were run and the results are summarized in Table II.

TABLE II—STAND OF GRASS IN SOIL SPRAYED WITH 2,4–D, 1000 PPM, ½ GALLON PER 100 SQUARE FEET

Date	Bent Grass	Kentucky Bluegrass	Chewings F.
Aug 11 to Oct 9....	Reduced by 30 per cent	Reduced by 10 per cent	Not reduced
Oct 11 to Nov 1....	Reduced by 20 per cent	Eeduced by 10 per cent	Not reduced
Nov 29 to Feb 12...	Reduced by 30 per cent	Reduced by 30 per cent	Not reduced
Dec 13 to Feb 11...	———	Reduced by 60 per cent	Reduced by 30 per cent
Jan 22 to Feb 9....	Reduced by 20 per cent	Reduced by 10 per cent	Not reduced
Feb 11 to Mar 23...	Reduced by 25 per cent	Reduced by 25 per cent	Not reduced

From these six tests it appears that the stand of bent grass and Kentucky grass is reduced when 2,4–D is applied to the soil at the time of planting. Chewings fescue is not reduced in stand to such an extent. Other grasses that were tested in duplicate tests and indicate reduced stand include, Rhode Island bent, Reed Canary grass, smooth broom grass, Canada bluegrass, crabgrass and orchard grass and Red Top. The stand of all clovers was drastically reduced. Tests included alfalfa, red clover, Ladino clover, wild white clover, and alsike clover

Grasses that were not reduced appreciably in stand include ryegrass, Chewings fescue.

Reduction in stand of grass when larger amounts of 2,4–D were applied was found to be true in the case of bent grass and Kentucky bluegrass and Chewings fescue. When double the usual application of 2,4–D was applied, bent grass was reduced by 90 per cent in stand, Kentucky bluegrass by 90 per cent, Chewings fescue by about 10 per cent. When four times the normal quantity of 2,4–D was applied all grasses were reduced at least 90 per cent in stand. This was repeated in two tests where eight times the normal amount of 2,4–D was applied, also where ten times the amount of 2,4–D was applied. When the concentration of 2,4–D was increased from 1000 to 2000 ppm. and applied at the rate of ½ gallon to each 100 square feet, bluegrass, bent grass and Chewings fescue were seriously reduced in stand. Application was made to the soil immediately after the seeding.

When 2,4–D is applied to the soil prior to planting the seed being sown on the treated soil and then covered with a light dressing of top soil, similar reduction in stand of grass was found to that when the surface of the soil was treated after planting. Soil sprayed with a normal concentration and rate of 2,4–D appears to reduce the stand of grass even after a period of 2 weeks time. When the soil is left unwatered the period is longer. When larger amounts of 2,4–D were applied to the soil before the planting of the grass seed, serious reductions in grass stands (allowing not over 10 per cent stand) were found with soil treated in July and seed sown in November. In this case the amount of 2,4–D was 10 times normal quantity applied.

SUMMARY

When 2,4–D is sprayed on lawn grass for purpose of controlling dandelion and plantain, good results were obtained after 30 days time. The lawn is essentially freed from weed growth of this type. Applications as described by Hamner and Tukey of 1000 ppm ½ gallon to 100 square feet have given satisfactory results as reported by Davis and others. Satisfactory control has been obtained from treatments made in May, June, July and August, September and October. Plantain and dandelion can be controlled and some clover left in the plantings when sprays are applied in August or later, as indicated by Farnham and Hallowell. Light applications and even wind blown spray are effective in controlling dandelions and plantain and will cause injury to many garden plants.[1] Re-infestation of soil from early applications of 2,4–D does not appear to be likely during the first season.

Improvement in turf is more dependent upon the proper use of fertilizers than upon application of a weed killer. The use of fertilizer to

[1]Some garden plants which were tested were: Bleedingheart *(Dicentra spectabilis)*, *Anchusa italica*, *Hosta*, *Heleborus* niger and *Pachysandra* were injured seriously in limited tests and among woody plants, "*Sambucus canadensis*, *Lonicera japonica*, *Robinia pseudoacacia*, and *Rhus Toxicodendron* were severely injured while *Tilia americana*, *Fraxinus americana*, *Rhus typhina*, *Vitis*, *Rubus* and *Prunus* species showed only local reaction and mature growth in *Rhododendron catawbiense*, *Vinca minor*, *Taxus cuspidata*, *Tsuga canadensis* showed little reaction as reported by Beatty and Jones.

stimulate the grass and crowd out the weeds is a possible way of controlling weeds in a lawn. In the tests described above, this was accomplished in 1-year's time. When 2,4–D is applied to the soil at the time of seeding, reduction in stand of most lawn grasses will result. This is in agreement with reports by U. S. D. A. by Farnham and Hallowell and others. This is especially true where larger amounts of 2,4–D are applied than is recommended for the control of weeds in the lawn. Application of 2,4–D at the usual rate can be made to young grass without serious injury, especially after the first cutting. With some annual weeds such as crabgrass the timely application of double the usual concentration of 2,4–D offers the possibility of preventing a stand of these grasses and consequent reduction of troublesome weeds in lawn areas.

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The Influence of Nitrate Level and Light Intensity on the Growth and Production of Greenhouse Roses

By KENNETH POST and JOSEPH E. HOWLAND,[1]
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FLORISTS express varied opinions on the optimum nitrate level for greenhouse roses. Seeley (3) reported the results of a careful 3-year study in which it was possible to maintain fairly definite nitrate levels in the soil. He found no significant increase in production at nitrate tests above 25 ppm[2], but had 50 ppm as his highest value.

The present 3-year study was made to determine the correlation between nitrate tests of 10, 25, 50, 75 and 100 ppm and rose production and stem length.

MATERIALS AND METHODS

Dormant, started-eye, budded plants of the variety Better Times, donated for the experiment by Jackson and Perkins Company, were planted on June 16, 1942. The plants had been stored at 30 to 40 degrees F until then. Production began in September, and the first-year data include September 1 through June 30, 1943 (10 months). The second-year data are for July 1, 1943 through June 30, 1944 (12 months), and the third-year data are for July 1, 1944 through May 17, 1945 (10½ months).

The plants were pinched for the first 2 months after planting. No further pinching was ever given. They were maintained in continuous production and never dried off, but were gradually cut back as the flowers were cut during April through June 1943, during March through May 1944, and during March through May, 1945. Manure mulches were never used.

The plants were grown in water-tight, V-bottom concrete benches. Each plot was 3 feet square and contained nine plants. There were four replicate plots of each treatment.

The soil, a Genesee silt loam, had been in sod for several years and was composted with manure in August 1941. Superphosphate (20 per cent P_2O_5) at the rate of 5 pounds per 100 square feet of bench area was incorporated into the soil before planting.

The manure in the compost supplied enough potassium for the first year. In July 1943, July 1944, and in February 1945, an application of 1 pound of muriate of potash and 2 pounds of superphosphate per 100 square feet of bench area was made. These three applications of fertilizers were enough to keep the P test above 5 ppm and the K test above 20 ppm at all times.

Flowers were cut each morning and the stems graded into lengths of 3 inches as is done by most commercial rose growers. For example, an 18-inch rose had a stem more than 18 inches long and less than 21

[1]The project was started by Dr. E. V. Staker of the Agronomy Department in 1940, and conducted by J. G. Seeley during 1941–43, and by Joseph E. Howland since July 1943. Iva E. Piper made the soil tests during 1944 and 1945. The work has been supervised by Dr. Kenneth Post. Fred F. Horton has been the grower.

[2]Spurway soil test value.

inches. Thus, the true average stem length of the 18-inch grade is 19½ inches. Accordingly, to determine the true average stem length in the present study, 1½ inches were added to the mean length as calculated by the 3-inch grade designations.

All drainage water was collected, and returned to the plot in the next watering. Thus, none of the soil nutrients were lost by leaching.

Calcium nitrate in water solution was added every third day (every fifth day in winter) during the first 2 years. Ammonium nitrate in water solution was used during the third year. The amount used was calculated to maintain the desired nitrate level in the soil. The soil was a new sod loam compost when the roses were planted; hence, during the first year the gradual breakdown of the manure and grass in the soil made it easy to maintain the desired nitrate levels without using much chemical nitrogen. Probably little manure remained after the first year, and the application rate for the chemical nitrogen had to be greatly increased for the succeeding years.

The soil was tested twice monthly by a modification of the Spurway system (2). To reduce variation, the nitrate solution was added before 10 a. m., and the soil samples taken at 1 p. m. on the second day after the nitrate solution was added. However, growth rates of the plants varied so much during this standard 2-day waiting period, because of differences in light intensity and temperature, that nitrate removal from the soil probably was far from constant. For the same reasons, the amount of watering necessary in this 2-day period varied. While none of the leachate was lost, variation in water requirements caused a non-uniformity in the amount of nitrate-N present in the leachate in the crocks at the time the soil was sampled. For example, a 10 ppm plot might have no leachate in the crock and consequently an above-normal nitrate test; whereas a 100 ppm plot might have nearly a gallon of leachate, hence a sub-normal nitrate test. Unfortunately, the various plots could not be watered at the same time and with the same amount of water. To maintain uniform conditions for water absorption by the plants, the forces with which the water was held by the soil in the various plots had to be uniform. Accordingly, water could not be added in uniform amounts at a standard time because rates of water loss from the plots were not uniform.

The light intensity outside the greenhouse was measured continuously by an automatic light recorder employing a Weston light meter. (1)

Results

Nutrient Levels:—Despite the careful attention given to estimating from the data of the most recent soil test the amount of nitrate that probably would be needed, there was constantly a considerable fluctuation above and below the desired soil tests during the 3-year test period. The magnitude of the deviation increased as the desired test became larger, a condition shown graphically in Seeley's paper, although he had 50 ppm as his highest test. The present study used nitrate tests as high as 100 ppm. Consequently, it would be more accurate to say that the soil tests in the present work normally were within these limits: 7 to 15 ppm, 15 to 35 ppm, 40 to 65 ppm, 65 to 95 ppm, and

95 to 145 ppm. For the 3 years studied, the actual soil nitrate tests averaged as follows in ppm:—

Desired Test	1942 to 1943	1943 to 1944	1944 to 1945
10	14	9	13
25	33	17	27
50	53	43	60
75	80	72	92
100	101	105	141

Probably a more accurate measure of the actual differentials in the amounts of nitrate-N available to the plants in the plots at the various desired nitrate tests is given by a comparison of the absolute amounts of the nitrogen fertilizer used for the five treatments. These data are given in Table I.

TABLE I—AMOUNT OF NITROGEN FERTILIZER USED, EXPRESSED AS POUNDS OF AMMONIUM SULFATE EQUIVALENT USED PER 100 SQUARE FEET OF BENCH AREA

Desired Test (Ppm)	Pounds Per 100 Square Feet		
	1942 to 43	1943 to 44	1944 to 45
10	0.23	3.41	3.38
25	0.59	5.97	4.77
50	1.24	7.79	6.28
75	1.92	9.98	7.40
100	2.61	11.55	7.98

Flower Production:—The data in Table II show that flower production tended to increase with each increment of nitrate-N. Only flowers which would be commercially salable are included. Such flowers had a stem length of more than 6 inches and had no defects in the flower or foliage.

TABLE II—EFFECT OF VARIOUS SOIL NITRATE TESTS* ON THE ANNUAL PRODUCTION OF BETTER TIMES ROSES

Nitrate Test (Ppm)	Flowers Per Plant			
	1942 to 43 (10 Months)	1943 to 44 (12 Months)	1944 to 45 (10½ Months)	Total
10	23.7	34.3	29.5	87.5
25	24.4	36.4	32.8	93.6
50	25.4	36.9	34.3	96.6
75	26.1	37.4	35.8	99.3
100	27.1	39.1	36.8	103.0
Least significant difference at 5 per cent level, according to Snedecor's method	2.3	2.8	2.9	——

*Spurway soil test value.

Production was not significantly less in the first 2 years as the nitrate test was decreased from 75 ppm, to 25 ppm. In 1944 to 45, the 75 ppm plots actually averaged 92 ppm, and there was a significant decrease in production at both the 25 ppm and 10 ppm tests. Statistical study of the interactions between nitrate test and months showed there was no need to alter the nitrate test with seasons. Table III records the monthly production per plant for the 32½ months of the 35 months the

plants were in the greenhouse. Figure 1 shows graphically that flower production was a direct function of light.

TABLE III—EFFECT OF VARIOUS SOIL NITRATE TESTS ON THE MONTHLY PRODUCTION OF BETTER TIMES ROSES

Nitrate Test (Ppm)	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1942 to 43—Average Production Per Square Foot												
10	—	—	3.44	3.22	1.58	1.89	1.33	1.63	1.53	2.55	3.08	3.55
25	—	—	3.67	2.98	1.67	1.83	1.61	1.22	2.00	2.33	2.89	4.17
50	—	—	3.87	3.14	1.42	2.33	1.42	1.00	1.83	2.09	3.37	5.03
75	—	—	3.70	2.94	1.37	2.33	1.42	1.42	1.89	2.28	3.76	5.00
100	—	—	3.87	2.67	1.98	1.59	1.28	1.67	1.59	3.26	3.83	5.42
1942 to 43—Average Stem Length (Inches)												
10	—	—	11.6	18.5	20.1	21.6	21.0	21.3	22.1	24.8	26.3	25.9
25	—	—	14.2	18.4	20.1	20.4	20.6	21.6	21.1	25.1	24.5	26.5
50	—	—	14.2	18.5	20.4	20.5	21.6	21.8	22.5	26.7	25.6	27.3
75	—	—	13.5	18.0	19.6	19.7	21.5	20.7	21.9	24.6	24.3	25.9
100	—	—	13.4	16.9	19.3	20.2	21.0	21.1	21.5	23.4	25.1	24.6
1943 to 44—Average Production Per Square Foot												
10	5.50	4.39	3.58	2.58	1.42	1.97	1.00	1.64	1.72	1.08	3.50	5.94
25	6.33	3.81	4.00	3.03	1.53	1.67	1.19	1.72	1.44	1.61	3.97	6.19
50	6.39	4.00	4.06	2.64	1.89	1.67	1.22	1.72	1.44	1.94	3.78	6.17
75	5.61	4.39	4.17	2.83	2.11	1.47	1.53	1.22	2.08	1.92	3.75	6.31
100	4.72	5.50	4.47	2.61	2.39	1.80	1.31	1.67	1.92	1.89	3.89	6:89
1943 to 44—Average Stem Length (Inches)												
10	20.7	20.3	21.0	20.9	21.4	21.2	21.0	20.2	24.4	26.2	25.7	22.7
25	20.0	21.0	21.6	21.4	21.7	21.1	20.7	21.0	23.7	27.8	26.3	22.9
50	20.3	20.6	20.9	21.6	21.1	21.0	20.9	20.4	24.1	26.2	25.5	21.9
75	20.9	20.0	21.2	20.7	20.9	20.9	20.2	21.6	23.3	27.5	25.8	22.7
100	20.9	20.1	19.5	21.0	20.4	19.8	20.6	21.0	24.7	25.7	25.7	22.7
1944 to 45—Average Production Per Square Foot												
10	6.03	4.19	3.72	3.03	1.44	1.56	1.69	1.61	3.03	1.64	1.56	—
25	6.42	5.14	4.81	3.17	1.64	1.69	1.75	1.39	2.36	2.28	2.11	—
50	6.56	5.33	4.53	2.81	2.39	1.75	1.69	1.86	2.50	2.47	2.39	—
75	6.61	5.53	4.81	3.22	1.94	2.25	1.72	1.92	3.08	2.19	2.53	—
100	6.50	6.36	4.58	3.58	2.47	1.78	1.94	1.58	3.28	2.46	2.19	—
1944 to 45—Average Stem Length (Inches)												
10	18.4	21.1	19.7	20.4	21.1	20.7	20.3	19.8	22.2	25.9	25.9	—
25	18.5	18.6	19.2	20.7	21.9	21.5	21.1	20.0	26.4	26.8	26.6	—
50	18.7	18.8	19.1	21.3	20.9	20.8	21.2	20.2	23.9	26.1	24.8	—
75	18.3	18.6	19.5	20.8	21.1	20.0	21.0	20.4	22.8	27.0	24.7	—
100	18.6	18.7	20.0	20.6	20.5	19.9	19.7	20.3	23.2	25.1	24.0	—

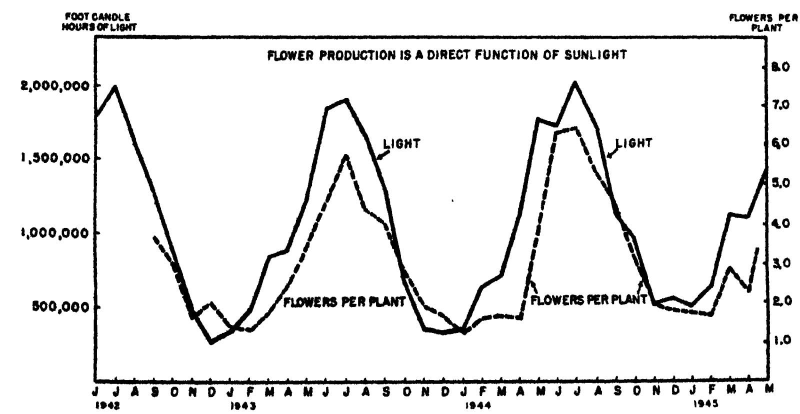

FIG. 1. Flower production and light.

Average stem length was not altered significantly at any nitrate test (Table IV), in any of the 3 years.

TABLE IV—EFFECT OF VARIOUS SOIL NITRATE TESTS ON THE AVERAGE STEM LENGTH OF THE CUT FLOWERS

Nitrate Test (Ppm)	Average Stem Length (Inches)		
	1942 to 43	1943 to 44	1944 to 45
10	18.8	19.6	19.9
25	18.8	19.9	20.5
50	19.4	19.5	19.9
75	18.5	19.6	19.8
100	18.2	19.3	19.5

SUMMARY

Maximum economical production occurred each year when the soil nitrate test was held between 25 and 75 ppm. Accordingly, there is a broad range for the nitrate test.

One hundred ppm is too expensive to maintain since it requires weekly applications of fertilizer. Also, there would be danger of fertilizer toxicity unless the soil was tested weekly to determine the amount of nitrogen to apply. Preliminary experiments indicate that stem length may be reduced when the nitrate test is above 125 to 150 ppm.

The lack of statistical significance in the interaction effect between nitrate test and months indicates that light intensity controls growth and flower production and that nitrate fertilization cannot overcome this effect.

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Selenium Studies with Some Flowering Greenhouse Plants

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During the past few years, the application of sodium selenate to the soil for control of certain pests on florist crops has received widespread publicity. Following the recommendations issued from time to time by Cornell University and the Ohio State University, growers have recognized the advantages of the method and a considerable number have made it a part of their pest control program. It is our purpose here to present some of the experimental work being done on the problem at the Ohio State University and Battelle Memorial Institute.[1]

Chrysanthemum

The control of pests on chrysanthemums is essential in producing flowers of high quality. Table I illustrates the effectiveness of sodium

TABLE I—Effect of Selenium Treatments for Chrysanthemums

Selenium Treatment		Average Number of Red Spiders Per Upper Leaf	Average Height of Plants at Time of Flowering (Cm)	Selenium Content of Foliage (Ppm)	
Ppm*	Sodium Selenate Per Square Foot (Gms)			Lower Leaves	Upper Leaves
0	0.0	71	119	—	—
2	0.08	50	119	12	11
4	0.16	49	121	20	7
6	0.23	20	120	25	14
7**	0.27	19	123	29	14
8	0.31	20	123	35	18
10	0.39	14	123	52	20
12	0.47	2	124	102	39
14†	0.54	4	121	127	54
16	0.62	1	121	200	94
20	0.78	4	117	201	101
30	1.17	0	113	330	174

*Parts of selenium per million parts of soil at 20 per cent moisture content.
**P-40 at 3 pounds per 100 square feet of soil surface.
†P-40 at 6 pounds per 100 square feet of soil surface.

selenate in controlling red spider mite on Princeton variety chrysanthemums. In this experiment the plants were grown singly in 2-gallon crocks, rooted cuttings being planted on March 10, 1945. Selenium treatments were applied on April 5. The population counts of red spiders were made about 2 months after treatment, on June 6. The plants were harvested September 28, when fully flowered, and samples of the foliage collected for selenium analyses.

It is evident that at 12 ppm of selenium (approximately ½ gram of sodium selenate per square foot of soil surface) control of red spiders was, for practical purposes, completely effective. No population counts are available on thrips, but examination of the foliage shows that considerable thrips damage occurred on the lower leaves of all plants

[1]Work at Battelle Memorial Institute conducted under the sponsorship of the Selenium Development Committee.

receiving less than 12 ppm of selenium, but was negligible at 12 ppm or more. Foliar nematode was controlled at 10 ppm or more.

Typical symptoms of selenium toxicity were almost entirely lacking in this experiment, even at the highest selenium levels. Table I shows that the height of the plants was reduced slightly at 20 and 30 ppm. At these selenium levels flowering of the plants occurred 7 to 12 days earlier than at lower concentrations. Otherwise, development was normal. Later experiments indicate that the varieties Princeton, Mrs. Kidder, Little America, Omega, and Sylvanna are relatively resistant to selenium toxicity, and that other varieties may not tolerate the selenium concentrations attained in the present experiment. Jewell, Ivanhoe, and Jemima are not tolerant to selenium.

Table I shows the selenium content of the foliage at the termination of the experiment. Correlations between these analyses and the red spider population counts cannot be made with finality, since the two sets of values were collected at different stages in the growth of the plants. Considering the selenium content of the lower and older leaves, it is tentatively suggested that the effective level for control of red spiders lies between 50 and 100 ppm of selenium in the foliage. This conclusion is substantially in agreement with the findings of Morris, Neiswander, and Sayre (7) and Neiswander and Morris (8).

Rate of Uptake:—The time required for plants to accumulate an effective amount of selenium, following the application of sodium selenate to the soil, is of considerable practical importance. If the plants are already badly infested at the time of application, some other control measure may be necessary during an initial period when selenium is being absorbed, but before a sufficiently high level has been reached. A study of the selenium content of plant samples taken from a crop of chrysanthemums at intervals following selenium treatment reveals certain interesting features of the absorption process.

Two varieties of chrysanthemums, Sylvanna and Omega, were used. On June 26, well-established cuttings of these varieties were shifted from 2-inch pots into flats measuring 21 x 34 x 6 inches deep. Plants were spaced approximately 7 x 7 inches in the flats. Two weeks later the plants were given a soft pinch to promote branching. On July 21 sodium selenate was applied to the soil, as a dilute water solution, to give selenium concentrations of 5, 10, and 20 ppm, corresponding to approximately ⅛, ¼, and ½ gram of sodium selenate per square foot of soil surface. Plant samples were taken 3 weeks after treatment, and at approximately 2-week intervals thereafter until October 9, when the last samples were collected. Table II shows the selenium content of the entire tops, collected at different intervals following treatment.

The lower leaves of both varieties showed considerable selenium injury in the plots treated with 20 ppm of selenium. Damage was slight at 10 ppm and negligible at 5 ppm.

At the application rate of 5 ppm, both varieties accumulated selenium rapidly during the first 3 weeks following its application to the soil. Plant selenium was relatively constant in both varieties for the remainder of the period covered by the experiment, indicating equili-

brium conditions between selenium uptake and the rate of plant growth.

When selenium was applied at the rates of 10 ,and 20 ppm, the period of rapid selenium accumulation was considerably longer. Equilibrium in plant selenium content appears to have been reached in the variety Omega at about 7 weeks following application. Beyond this point, the plant selenium remained fairly constant. In the variety Sylvanna, maximum selenium accumulation occurred at about 7 weeks in the plot treated at 10 ppm, and at 9 weeks in the 20 ppm plot. There was a marked decline in plant selenium following these maxima. It has not been possible to correlate this difference in varietal response with any detectable growth differences.

TABLE II—SELENIUM APPLIED ON JULY 21, TO WELL-ESTABLISHED PLANTS

Variety	Selenium Treatment		Selenium in Plants, on the Basis of Dry Tissue (Ppm)				
	Ppm Se	Sodium Selenate Per Square Foot (Gms)	Aug 10	Aug 22	Sep 10	Sep 26	Oct 9
Sylvanna	5	1/8	64	69	75	66	62
Omega	5	1/8	73	90	76	83	98
Sylvanna	10	1/4	157	284	428	395	287
Omega	10	1/4	149	220	325	337	330
Sylvanna	20	1/4	344	510	690	708	608
Omega	20	1/4	296	408	618	605	623

Data presented in Table I suggest that for effective red spider control the minimum concentration of selenium in the plant foliage lies between 50 and 100 ppm. Therefore, in the present experiment, effective plant selenium concentration were attained within the first 3 weeks following the application of sodium selenate to the soil. These concentrations were maintained during the entire period covered by the experiment.

Effect of Sulfur:—Several investigators (1, 2, 4, 5, and 6) have reported that the sulfur content of the nutrient medium influences both the uptake of selenium by plants, and its toxicity to the plants. Their data indicate that an increase in the amount of available sulfur tends to inhibit the accumulation of selenium by the plant, and to reduce the injurious effects of that which is absorbed. It is believed that this principle may be applied advantageously in the use of selenium for greenhouse pest control. In the present experiment the sulfur-selenium relationship has been investigated on chrysanthemums, using six different selenium salts: the selenates of calcium, copper, potassium, and sodium, and the selenites of calcium and sodium.

Rooted Snow chrysanthemum cuttings were planted in 6-inch pots on August 21, 1945. Selenium treatments were made on September 17. On one-half of the pots the application was made by mixing an appropriate amount of the selenium salt with a tablespoonful of gypsum (as a source of slowly available sulfur in sulfate form) and applying this mixture to the soil as a top dressing, followed by watering. On the remaining one-half of the plants the method of application was similar except that finely ground limestone was substituted for gyp-

sum. Selenium levels of 10, 20, and 30 ppm were established, corresponding to sodium selenate at the rates of 1/5, 2/5, and 3/5 gram per square foot of soil surface. Check plants were treated with gypsum or limestone, without the addition of selenium. Two replications were made of each treatment.

Green aphids from chrysanthemums in another greenhouse were transferred to all plants 2 weeks after the application of selenium. On December 27, aphid population counts were made on the stem tips of all selenium-treated plants. On the controls, however, the infestation was so severe that this was not feasible. Instead, the aphids from several stem tips were brushed off and collected into a single mass. This was mechanically sub-divided into units small enough to be counted, and from these counts an estimate was made of the population per tip.

The plants were harvested on December 31, when in full flower, and the entire tops dried for selenium analyses. The size of sample required for reliable determinations necessitated combining the two replicates of each treatment into a single sample.

Plants receiving 20 and 30 ppm of selenium, diluted with limestone, exhibited recognizable symptoms of selenium toxicity within a week after application. Symptoms noted first were yellow chlorosis of the terminal growth, and a tendency of the foliage to wilt even when adequately watered. Plants treated with comparable amounts of selenium, diluted with gypsum, were entirely normal in appearance at this time.

The inhibition of selenium toxicity by gypsum was evident throughout the experiment. This effect was most striking at the higher selenium levels. Typical symptoms of selenium toxicity in the older plants included: Chlorosis, marginal burning, or death of the older leaves; stunting; and, in some instances, death of the entire plant. Seven out of 12 plants receiving 30 ppm of selenium mixed with limestone died before flowering; of 12 comparable plants receiving 30 ppm of selenium mixed with gypsum, only one died. Twenty ppm of selenium with gypsum was slightly less toxic than 10 ppm with limestone. The selenates of calcium and sodium were somewhat more toxic than the corresponding selenites at comparable concentrations. Fig. 1 shows a typical example of the inhibition of selenium injury by gypsum.

Table III gives aphid population counts on plants in the different treatments. The check plants were seriously damaged by this pest, and failed to produce flowers. All of the selenium applications resulted in some degree of protection against aphid damage, but not all were satisfactory in this respect. Twenty ppm of selenium, applied with gypsum, gave the most effective aphid control combined with minimum selenium damage, for all but one of the selenium salts used. For sodium selenite, the best treatment was 30 ppm of selenium, applied with gypsum.

Table IV gives the selenium content of plants from the various treatments. The accidental loss of several samples makes the data incomplete, but certain conclusions can be drawn from a consideration

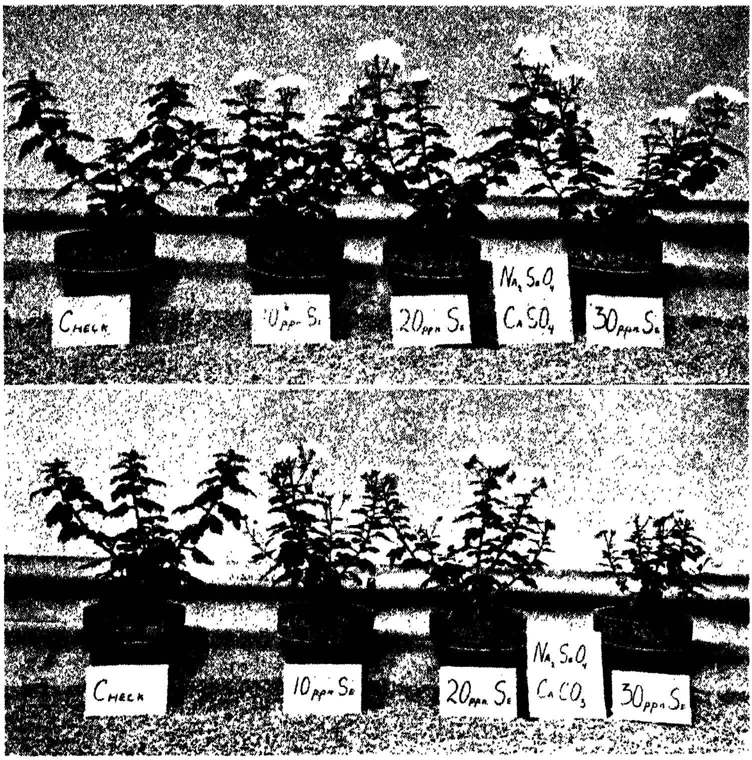

FIG. 1. Response of Snow chrysanthemums to soil application of sodium selenate mixed with gypsum (upper series), and with limestone (lower series). Treatments (left to right) are: 0, 10, 20, 30 ppm of selenium. Photographs taken December 31, 3½ months after application of sodium selenate.

of the available values. The accumulation of selenium by the plants, from a given rate of application to the soil, was usually considerably less when the selenium was applied with gypsum than when it was applied with limestone. This fact probably explains, to a large degree, the inhibition of selenium injury by gypsum, mentioned previously. It is of interest, however, that plants treated with 20 ppm of selenium with gypsum usually accumulated somewhat more than those receiving 10 ppm with limestone. Yet the former treatment proved less toxic to the plants and equally effective for the control of aphids. This is insufficient evidence to permit the recommendation of gypsum or some other source of available sulfate as a carrier for selenium in commercial practice. It is suggested, however, that further investigations should be made on the desirability of using high-sulfur carriers for the application of inorganic selenium salts.

The inhibiting effect of gypsum on selenium uptake by plants may have practical applications of a different nature. In the event that an overdose of selenium is applied to a crop by mistake, with resulting

TABLE III—SELENIUM APPLIED ON SEPTEMBER 17. APHID COUNTS MADE DECEMBER 27

Selenium Salt Applied	Average Number of Living Aphids Per Stem Tip, on Plants Receiving the Following Selenium Treatments							
	Selenium Applied With Gypsum				Selenium Applied With Limestone			
	No Se*	10 Ppm Se	20 Ppm Se	30 Ppm Se	No Se*	10 Ppm Se	20 Ppm Se	30 Ppm Se
$CaSeO_4$...	600	40	0	0	600	0	0	0**
$CuSeO_4$..	600	13	0	0	600	1	0	0**
K_2SeO_4...	600	25	1	0	600	1	0	0**
Na_2SeO_4..	600	25	1	0	600	23	0	0**
$CaSeO_4$...	600	115	5	0**	600	33	2	—†
Na_2SeO_3..	600	128	45	2	600	18	1	2**

*Values in this column estimated. Aphid damage so severe that plants failed to flower.
**One plant died before flowering as a result of selenium toxicity.
†Both plants died before flowering as a result of selenium toxicity.

damage to the crop, the application of gypsum or some other source of available sulfur should be effective in reducing damage and saving the crop. Further, if vegetables are to be grown on soil previously treated with selenium, treatment of the soil with high-sulfur fertilizers should increase the margin of safety with respect to uptake of selenium by the vegetable crop.

SELENIUM IN VEGETABLE CROPS

The degree of absorption of selenium by a vegetable crop, following a florist crop on selenium-treated soil, has not been thoroughly investigated. In a soil bed watered by sub-irrigation, onions (sets) and lettuce, planted 7 months after the application of sodium selenate at ¼ gram per square foot, absorbed small but appreciable amounts of selenium during their first 2 months of growth. Analysis of the plants showed a selenium content of 3.8 ppm in lettuce and 31.3 ppm in onions, on the basis of dry material. On a fresh-weight basis the values were 0.24 ppm for lettuce, and 3.44 ppm for onions.

The maximum safe rate of selenium ingestion for humans has not been determined with certainty. However, the results of Smith and Lillie (9) and Smith, Westfall, and Stohlman (10) suggest that a daily intake of 1 mg of plant selenium should not be harmful to an

TABLE IV—SELENIUM APPLIED ON SEPTEMBER 17. SAMPLES COLLECTED ON DECEMBER 31

Selenium Salt Applied	Selenium Content, on the Basis of Ppm in Dry Tissue, of Plants Receiving the Following Selenium Treatments					
	Selenium With Gypsum			Selenium Applied With Limestone		
	10 Ppm Se	20 Ppm Se	30 Ppm Se	10 Ppm Se	20 Ppm Se	30 Ppm Se
$CaSeO_4$....	42	160	143	115	—*	—*
$CuSeO_4$....	57	141	157	182	177	202
K_2SeO_4....	54	112	164	89	129	152
Na_2SeO_4...	35	95	143	70	126	—*
$CaSeO_3$....			42	20		
Na_2SeO_3...	11	22	42	20	42	58

*Analytical samples accidentally lost.

adult. On the basis of this assumption, it is calculated that an adult could safely consume approximately 9 pounds of the lettuce or 0.6 pounds of the onions per day for an indefinite period. Thus, if these vegetables were used in normal proportion in the diet, they would be entirely safe.

The difference in selenium accumulation between onions and lettuce is significant. On a fresh-weight basis, onions accumulated 14 times as much selenium as lettuce. Hurd-Karrer (3) has shown that, in general, crops which have a high sulfur requirement also store relatively large amounts of selenium. Such crops are onions and most members of the mustard family (mustard, cabbage, broccoli, cauliflower, etc.). It would certainly seem advisable to avoid growing these crops on soil previously treated with selenium. Most other vegetable crops appear to have a lower capacity for accumulating selenium. As pointed out above, a liberal application of gypsum or some other source of sulfate might be expected to reduce materially the likelihood of accumulating harmful amounts of selenium in vegetable crops.

COMMERCIAL APPLICATION

The following tests were conducted to determine the usefulness of this insecticide on a wide variety of greenhouse plants grown in the usual commercial manner.

Pot Chrysanthemums:—Rooted cuttings of a number of varieties were placed in 6-inch azalea pots on May 16. The soil mixture used consisted of 1 part each of silt loam, sand, sedge peat moss, and well-rotted manure. Selenium ws applied on June 12 in the following manner:

0.625 grams of sodium selenate per square foot

- Helen Frick
- Yellow Beauty
- Gypsy
- Bronze Frick
- Little America
- Richard Mandel
- Sungold

¼ teaspoonful of P–40 per pot (3 pounds per 100 square feet)

- Glitters
- Bronze Masterpiece
- Justrite
- Red Rolinda
- Queen of the Pinks

¼ teaspoonful of limestone containing 2 per cent sodium selenate (equivalent to the P–40 treatment)

- Alameda
- Blazing Gold
- Beautiful Lady
- Bonnafon De Luxe
- White Frick
- Christina
- Sunray

There were four pots of each of the above varieties in each of the plots, and a similar number of the same varieties were reserved as check or untreated plants. These untreated plants were sprayed in the usual commercial manner with No-Py-Ro at 1–400, Nicotine at 1–400, and SALP at 2 pounds per 100 gallons with 3 pounds of sugar as a sweetening agent. No spray or fumigation treatment was given the plants treated with selenium.

The sodium selenate application was made at slightly higher rate than is normally recommended for chrysanthemums, and the varieties Helen Frick and Bronze Frick showed injury in the form of yellowing of lower leaves. No other varieties appeared to be injured in this high organic soil mixture. In early September another application of limestone was made to the plants as there were a considerable number of thrips on the tops of the plants. The other plots showed no thrips injury. The prevalent pests that were adequately controlled in these tests were red spider, thrips, and aphids, but there were not enough leafroller and foliar nematode present to draw any conclusions on these pests.

The results of this test indicated that the use of sodium selenate or P–40 on pot chrysanthemums in a highly organic soil mixture is practical for the control of red spider, thrips, and aphids. Where no attempt is made to provide an unusually favorable soil mixture for root growth, and if the selenium is not carefully applied, one may expect to cause damage as many chrysanthemum varieties have shown damage from selenium treatments in commercial florists' greenhouses.

Pot Gardenias (Gardenia veitchi):—The control of mealybugs on gardenias has long been a serious problem. To determine the effectiveness of sodium selenate on this pest, four test plots were established. Each plot consisted of four 6-inch azalea pots containing two well established plants of Gardenia veitchi in a mixture of one part silt loam and one part acid peat moss. The following treatments were made on June 12:

Check — untreated

0.625 grams of sodium selenate per square foot

¼ heaping teaspoonful of P–40 per pot (¼ gram of sodium selenate per square foot).

½ heaping teaspoonful of P–40 per pot (½ gram of sodium selenate per square foot).

There was no evidence of selenium injury to the plants, and the mealybug infestation was unchecked. Apparently this pest does not respond to control by selenium, or the gardenia does not accumulate effective amounts of the toxicant.

Christmas Begonias (Begonia socotrana):—The control of mealybugs on this plant is difficult as many spray materials cause severe burning of the leaves or check the growth of the plant. Twenty-five well established plants in 4-inch pots in a low organic silt loam soil were treated on July 13 with ¼ gram of sodium selenate per square foot. The plants had a moderate infestation of mealybugs both on the leaves and stems. Three days after treatment, many of the plants showed severe leafdrop and brown spots appeared on the upper foli-

age of the plants. No control of mealybugs was noticed on the leaves that dropped and mealybugs on the stems were not affected. Apparently the begonia is too sensitive to treat with sodium selenate.

Hydrangea (Hydrangea macrophylla):—The control of red spider and aphids on hydrangeas is difficult because of the compact habit of growth of the plant. To thoroughly cover all lower leaf surfaces with a high pressure sprayer is difficult, and failure to do so requires very frequent spraying to keep the infestation in check. Three varieties of hydrangeas were grown in both 5- and 6-inch pots during the summer in a mixture of 2 parts silt loam, 1 part sand, 1 part sedge peat moss, and 1 part well rotted manure. The following treatments were used:

¼ teaspoonful of P–40 on 5-inch pots and ¼ heaping teaspoonful of P–40 on 6-inch pots of Hydrangea Merveille — corresponds to 3 pounds of P–40 per 100 square feet.

¼ heaping teaspoonful of P–40 on 5-inch pots and two ¼ heaping teaspoonful of P–40 on 6-inch pots of Hydrangea Merveille — corresponds to 6 pounds of P–40 per 100 square feet.

¼ gram of sodium selenate per square foot on 5-inch and 6-inch pots of Hydrangea Rosabelle.

½ gram of sodium selenate per square foot on 6-inch pots of Hydrangea Strafford.

No treatment was applied until the middle of June, when the plants were well established. All plants were moderately infested with red spider and aphids at the time of treatment, and, after 5 to 6 weeks, these pests were killed and no further infestation occurred. The carryover effect of selenium from the growing season apparently is questionable as the treated plants showed severe aphid infestation during the forcing season. Previous tests have shown that selenium applied during the forcing season has little or no effect on pest control presumably because hydrangea stem is too woody for movement of the selenium into the leaves. Attempts to mix P–40 with the potting soil for the rooted cuttings of hydrangea resulted in failure of the plants to become established, severe chlorosis appeared, and a majority of the young plants died.

Cyclamen (Cyclamen africanum):—Infestation of red spider, mite, aphids, and thrips cause considerable difficulty in the culture of this crop. Well established cyclamen plants in both 5- and 6-inch pots were treated in mid-June with ¼, ½, ¾, and 1 gram of sodium selenate per square foot, and P–40 at both 3 and 6 pounds per 100 square feet. Within 2 to 3 weeks after treatment, many of the plants were checked in growth, as compared to similar plants not treated with selenium which were sprayed with various insecticides to control the pests mentioned. On September 1, approximately one-half of the treated plants were discarded since they were badly injured and attempts to produce commercially suitable plants seemed impractical. The remaining plants were grown in the usual manner and in early November a number of thrips were observed on all of the plants. Apparently the selenium was either completely absorbed by the older tissues of the plants, considerable leaching from normal watering had occurred,

or a combination of both factors may have taken place. It was apparent from these tests that the use of selenium on cyclamen is of doubtful value because of the dangers attending its use.

Carnations in Soil:—Two plots of 12 plants each of the variety Olivette were benched the first week of July in soil. Four weeks after benching one plot was treated with sodium selenate at ¼ gram per square foot and the other plot received sodium selenate at ½ gram per square foot. At the time of treatment all the plants were moderately infested with red spider and aphids. Within 2 weeks the plants receiving ½ gram of sodium selenate showed a reduction in the number of insects but the ¼ gram plot required about 4 weeks for this effect. In 6-weeks' time the new growth of plants in both plots were free of red spider and aphids and only a limited number of red spider were found on the older lower leaves. The plants were removed in late December and the effectiveness of sodium selenate in controlling red spider and aphids on carnations in soil was very evident. No appreciable differences were apparent in the growth of the plants in each plot and both were acceptable from the commercial growers' standpoint.

It is interesting to note from experiments conducted with commercial florists that sodium selenate is most satisfactory if applied twice during the life of a carnation crop. In commercial practice, field grown plants are benched in July, and an application of sodium selenate at one-fourth gram per square foot should be made when the plants are well established which is about 4 weeks after benching. This will protect the crop during fall and early winter. Another application at ¼ gram per square foot should be made in December to protect the crop in late winter through spring until the plants are removed from the bench which is in late June or early July. This double application appears to be the safest and most practical method of applying sodium selenate to soil grown carnations for the control of red spider and aphids.

Carnations in Gravel Culture:—The necessity for maintaining a regular pest control program until sufficient time has elapsed for the distribution of selenium into all parts of the plant was well illustrated in the following experiment. The varieties King Cardinal, Arundel, Olivette, and Pelargonium were benched in gravel culture on May 28, and sodium selenate was placed in the nutrient solutions at the rates of 2, 5, and 10 parts per million. The plants were heavily infested with red spider and aphids at the time of benching and no attempt was made to control these pests other than the initial treatment with selenium. In 5 weeks' time, the plants were almost dead from the depredation of the pests.

As a result of this preliminary treatment, another experiment was begun. The variety Olivette was benched in gravel culture the first week of July and the following treatments were established:

2, 5, and 10 ppm sodium selenate added weekly
2, 5, and 10 ppm sodium selenate added every other week
2, 5, and 10 ppm sodium selenate added every third week
2, 5, and 10 ppm sodium selenate added every fourth week

All plants were heavily infested with red spider at the time of benching. Within a month the plots receiving selenium every third and every fourth week had to be discontinued as the red spiders had not been killed and the plants were almost dead. The plots with selenium added every two weeks were alive but had grown very little. The plots with weekly additions of selenium were the best, but only the plants in the 10 ppm level of sodium selenate were comparable to commercially acceptable plants. The plants in the 2 and 5 ppm level plots were not showing much growth and the control of red spider was negligible. At the end of December the plants in the 2 and 5 ppm level of sodium selenate were still infested with spider and were stunted in their growth. The weekly addition of 10 ppm of sodium selenate to carnations in gravel culture appears to be the most satisfactory method of controlling red spider and aphids. A period of 4 to 6 weeks should be allowed for the selenium to be distributed to all parts of the plant and control of red spider and aphids during this interim period with standard insecticides is essential.

Discussion and Conclusions

The results of all of these tests show that the use of selenium as a practical means of controlling red spider and aphids on carnations, chrysanthemums, and hydrangeas offers distinct possibilities. Chrysanthemum varieties differ in their response to selenium, some varieties being tolerant and others not, and further investigational work is necessary to determine how useful this material will become on chrysanthemums. Of the varieties tested to date only Ivanhoe, Jemima, and Jewell have been found to be particularly sensitive to selenium injury. The foliar nematode is readily controlled in chrysanthemum leaves by applications of selenium to the soil. Thrips control on tolerant crops is not entirely reliable, and it would appear that the use of other insecticides is necessary to supplement the use of selenium in combatting this pest.

One hundred ppm of selenium in the lower leaves of the plants appears to be an effective level for the control of red spider and aphids. An allowance of 3 to 4 weeks should be made for the concentration to reach this point. The use of either ¼ or ½ gram of sodium selenate per square foot is sufficient to cause accumulations of selenium to this effective level, but the tolerance of the crops must be taken into consideration. Sodium selenate at the rate of ¼ gram per square foot is probably the safest and most practical treatment for most crops, but on tolerant crops such as carnations it may be desirable to repeat the treatment after 2 to 4 months. It is suggested that on sensitive crops the ¼ gram treatment might best be made as two applications of ⅛ gram per square foot, 2 to 4 weeks apart. Further investigation is necessary to establish the feasibility of this schedule. The initial application of sodium selenate in liquid form should not be made until the plants are well established.

The growing of edible crops on soils previously treated with selenium cannot be recommended, pending more complete information on the persistence of selenium in the soil and its uptake by vegetable

plants. This problem represents a basic disadvantage of the selenium method of pest control, but the preliminary data presented here are encouraging. The results with lettuce and onions suggest that proper selection of the vegetable crop to be grown, plus treatment of the soil with gypsum to reduce selenium absorption, may eventually remove any danger from this source. Top-dressing the soil with gypsum or some other form of available sulfate is also suggested as a corrective treatment in cases where a florist crop shows damage due to selenium toxicity.

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Pruning Experiments with Greenhouse Roses

By J. R. KAMP and F. F. WEINARD, *University of Illinois, Urbana, Ill.*

FOUR-YEAR-OLD rose plants in three varieties were used in the experiment. Approximately one-fifth of these plants were grown in haydite, the rest in soil, but since no differences in trend were apparent between the two media, all results were combined for presentation.

After having been dried off for three weeks, the rose plants were cut back on July 17, in four groups, to 6, 12, 18, and 24 inches respectively. The various groups were evenly distributed throughout the house. Within a week, all plants were breaking freely. On August 9, the number of new shoots were counted and tabulated as shown in Table I.

TABLE I—NEW SHOOTS PRESENT AUGUST 9, 1944, ON ROSES CUT BACK JULY 17, 1944

No. of Plants	Cut Back to (Inches)	Average Number of Breaks at Different Levels				
		0 to 6 Inches	6 to 12 Inches	12 to 18 Inches	18 to 24 Inches	Totals
			Lucile Hill			
24	6	5.1	—	—	—	5.1
24	12	2.3	7.2	—	—	9.5
20	18	1.2	3.0	9.6	—	13.8
32	24	1.1	1.8	3.3	9.7	15.9
			Peters' Briarcliff			
40	6	6.2	—	—	—	6.2
40	12	2.9	7.9	—	—	10.8
40	18	1.0	4.6	10.7	—	16.3
40	24	0.9	2.6	5.6	15.2	24.3
			Sunglow			
39	6	6.6	—	—	—	6.6
40	12	2.7	9.4	—	—	12.1
39	18	0.8	4.7	14.1	—	19.7
38	24	0.5	1.8	5.1	21.8	29.1
			All Varieties			
103	6	6.1	—	—	—	6.1
104	12	2.7	8.3	—	—	11.0
99	18	1.0	4.3	11.8	—	17.2
110	24	0.8	2.0	4.8	15.9	23.5

It was evident that with each 6-inch increment removed, the total number of shoots was reduced. In all cases, more than half of the shoots arose from the top 6 inches. If the term bottom break be applied to all breaks arising within 6 inches of the soil level, then the greatest number of bottom breaks was to be found in those plants cut back to the 6 inch level, the number decreasing rapidly as the plants were less severely pruned.

Flower production records from the first of October to the end of March are shown in Table II. In each case, the more severely the plants were pruned, the greater was the reduction in total number of flowers cut, with a similar but not so pronounced trend in average stem lengths. If, for the combined varieties, the bloom yield from those plants cut to

TABLE II—Flower Production of Roses in Pruning Experiment October 1, 1944 through March 31, 1945

Number of Plants	Cut Back to (Inches)	Average Number of Flowers Per Plant	Average Stem Length (Inches)
		Lucile Hill	
24	6	8.7	11.5
24	12	10.0	11.8
20	18	11.4	12.3
32	24	12.6	12.4
		Peters' Briarcliff	
40	6	7.7	11.0
39	12	11.1	11.2
40	18	13.1	12.2
40	24	14.6	12.3
		Sunglow	
37	6	11.5	11.2
40	12	12.7	11.3
38	18	14.5	11.2
38	24	17.0	12.5
		All Varieties	
101	6	9.4	11.2
103	12	11.5	11.4
98	18	13.3	11.8
110	24	14.9	12.4

24 inches is taken as 100 per cent, the yields from the 18, 12, and 6 inch prunings were 89, 77, and 63 per cent, respectively.

This experiment indicates rather conclusively that severe pruning as a method of rejuvenating old rose plants is not successful. It also indicates that the production of bottom breaks, if made at the expense of total number of breaks, is unprofitable. There was no indication that 24 inches was the ideal height to prune or that this height gave maximum production. This matter is being further investigated.

The Influence of Various Soil Amendment Materials on the Growth and Flower Production of Greenhouse Roses

By KENNETH POST and JOSEPH E. HOWLAND,[1] *Cornell University, Ithaca, N. Y.*

FLORISTS annually spend large sums of money in the preparation of special soil mixtures for their crops, often different mixtures for each crop. Much labor is used each year to replace the "old" soil after it has been used in the greenhouse for 1 year, partly on the assumption that a freshly prepared soil mixture will have more nearly the exact structure needed for the crop (or that a new mixture is necessary if a different crop is to be grown).

Rose growers in particular feel that special soil mixtures are necessary if adequate soil aeration is to result under the packing action of the heavy, frequent waterings.

Observation of the increase in root growth which results when peat is added to the soil in relatively large amounts has convinced many florists that peat is indispensable in soil mixtures. The greater water-holding capacity of the peat usually is given as the chief reason for the observed increase in root growth.

Early in the research on automatic watering it became apparent that soils containing the large amounts of peat usually considered by rose growers to be essential did not provide the best conditions for the required capillary movement of water. When the peat was omitted, flower production of the roses did not decrease.

Thompson (2) obtained significant increases in flower production of greenhouse roses only when at least 50 per cent muck (by volume) was added to his soil, a heavy clay. Similar results were obtained for mucks from New Jersey, Indiana, and Michigan for the 3 years. Wilde & Link (4) reported that vegetative growth and flower production of greenhouse roses were not increased significantly by the addition of 25 per cent peat (by volume) to a Hagerstown silty clay which cracked badly on drying. The use of 50 per cent peat by volume did produce significant increases.

Florists normally use soils which are more porous than are silt clays, and usually either compost the soil with manure or use a field sod. Rarely is peat used in a soil mixture at a rate in excess of 20 per cent peat by volume. Most of the mixtures contain 5 to 10 per cent or less of each of the amendment materials.

Volz and his co-workers have studied carefully for a number of years the growth of various greenhouse plants in seven Iowa soil types which vary considerably in their physical properties. Volz and Stenstrom (3) reported no difference in flower production when uniform nutrient and moisture levels were maintained.

[1]The project was established by John G. Seeley and conducted by him until July 1943. Joseph E. Howland has been in charge of the study since that time. Fred F. Horton has been the grower. The soil testing has been done by Iva E. Piper during 1944 and 1945. All work has been under the supervision of Dr. Kenneth Post.

Materials and Methods

During the past 3 years, Better Times roses were grown at Ithaca in the following 11 modifications of a Genesee silt loam sod which had been composted with manure (25 per cent by volume) for 9 months:

25 per cent Maine Sphagnum peat
50 per cent Maine Sphagnum peat
25 per cent cinders (½ to 1 inch size)
50 per cent cinders (½ to 1 inch size)
25 per cent Haydite ("C" grade, ¾ inch maximum)
50 per cent Haydite ("C" grade, ¾ inch maximum)
15 per cent excelsior (Cuprinol treated[2])
15 per cent excelsior (asphalt treated[2])
25 per cent Maine sphagnum peat plus 25 per cent cinders, (½ to 1 inch size) compost with 3 inch excelsior mulch (Cuprinol or asphalt treated[2]) compost not amended

These amendment materials are the ones most commonly recommended by florists "to increase soil aeration."

Waterproof V-bottom concrete benches were used. Each plot was 3 feet square and contained 9 plants except in the treatments where excelsior was added to the soil. In these treatments, one plot was 3 x 4 feet and contained 12 plants. There were only three replications for these two treatments but there were four replications for each of the other nine treatments.

Dormant, started-eye Better Times plants, donated for the experiment by Jackson and Perkins company, were planted on June 15, 1942. The plants had been stored at 30 to 40 degrees F until then. Production began in September, and the first year data include September 1, 1942 through June 30, 1943 (10 months), the second year data include July 1, 1943 through June 30, 1944 (12 months) and the third year data include July 1, 1944 through April 30, 1945 (10 months).

The plants were pinched for the first 2 months after planting and no further pinching was ever given. They were maintained in continuous production and never dried off, but were gradually cut back as the flowers were cut during April, May, and June 1943, and during March, April, and May, 1944.

No manure mulch was ever used on any plot. Soils were tested twice each month by the Spurway system. Nitrates were maintained at 25 to 100 ppm by applications of ammonium sulphate.

The soil reaction (pH) was adjusted to pH 6.2 to 6.4 before the plots were planted. The pH remained between 6.0 and 6.7.

Superphosphate was added to the soil at the rate of 5 pounds per 100 square feet of bench area before the crop was planted. The manure in the compost supplied enough potassium for the first year.

[2]Cuprinol is a proprietory copper naphthanate. The excelsior was dipped in Cuprinol or asphalt, then allowed to drain. The asphalted excelsior was dipped a second time after it had dried. Cuprinol was used for the excelsior on two of the mulched plots and asphalt on the excelsior of the other two plots. In July 1943 the mulches were replaced on all four plots by a new Cuprinol-treated mulch.

In July 1943, July 1944, and in February 1945, an application of 4 pounds of complete fertilizer (5–10–5) per 100 square feet of bench area was made. These three applications of complete fertilizer were enough to keep the P test above 5 ppm and the K test above 20 ppm.

All plots were surface watered at 8 cm capillary tension (measured with mercury tensiometers). In other experiments, the authors found that flower production of greenhouse roses was highest when the soil was kept as wet as possible without water-logging it.

Flowers were cut each morning and the stems graded into lengths of 3 inches as is done by most commercial rose growers. For example, an 18-inch rose had a stem more than 18 inches long and less than 21 inches. Thus, the true average stem length of the 18-inch grade is 19½ inches. Accordingly, to determine the true average stem length in the present study, 1½ inches were added to the mean length as calculated by the 3-inch grade designations.

RESULTS

Flowers:—The data in Table I show that flower production in the various treatments was similar. Production was decreased significantly (at the 5 per cent level) in the first and second years in the soil containing 25 or 50 per cent Haydite and in the mulched soil. Production also was reduced significantly in the second year in the soil containing 15 per cent excelsior treated with Cuprinol. In the third year, production was decreased significantly where 25 per cent cinders or 50 per cent Haydite had been incorporated in the soil.

TABLE I—EFFECT OF SOIL MIXTURES ON FLOWER PRODUCTION OF BETTER TIMES ROSES

Treatment	Flowers Per Plant			
	1942 to 43 (10 Months)	1943 to 44 (12 Months)	1944 to 45 (10 Months)	3-Year Total
25 per cent peat	25.3	40.4	31.7	97.4
50 per cent peat	24.8	39.3	31.5	95.6
25 per cent cinders	26.2	37.5	29.2	92.9
50 per cent cinders	25.7	37.6	30.8	94.9
25 per cent Haydite	23.0	36.9	30.8	90.7
50 per cent Haydite	22.7	35.7	28.2	86.6
15 per cent excelsior (Cuprinol-treated)	26.5	37.1	31.9	95.5
15 per cent excelsior (asphalt-treated)	26.8	38.4	32.6	97.8
25 per cent peat and 25 per cent cinders	25.8	39.6	30.4	95.8
Compost mulched	23.1	35.8	30.3	89.2
Compost not amended	25.7	40.9	32.4	99.0
Average	25.1	38.1	30.9	94.1
Least significant difference at 5 per cent level according to Snedecor's method	3.6	3.5	2.2	—

The average stem length of the cut flowers was not altered significantly by any of the treatments, as is shown by the data in Table II.

Soil Structure and Root Growth:—The soil was observed to pack considerably during the study, especially the compost soil. A very substantial force was required during the third year to push the soil sampling tube to the bottom of the soil. The soil containing peat was at the other extreme for degree of compactness, since even at the end of the experiment it was relatively easy to scoop out the soil.

Root growth was observed to vary markedly in various soil mixtures. The soil containing 25 or 50 per cent peat was completely ramified by a mass of fibrous roots, while in the other extreme, *i. e.* the compost, there were relatively few, small roots.

TABLE II—EFFECT OF SOIL MIXTURES ON AVERAGE STEM LENGTH OF THE CUT FLOWERS

Treatment	Average Stem Length (Inches)		
	1942 to 43	1943 to 44	1944 to 45
25 per cent peat	21.0	21.3	19.6
50 per cent peat	20.2	21.2	19.8
25 per cent cinders	19.9	21.1	19.5
50 per cent cinders	19.4	20.6	19.1
25 per cent Haydite	19.5	21.0	20.5
50 per cent Haydite	19.3	20.4	19.6
15 per cent excelsior (Cuprinol-treated)	19.1	20.4	19.1
15 per cent excelsior (asphalt-treated)	19.3	20.3	18.7
25 per cent peat plus 25 per cent cinders	19.8	20.5	18.8
Compost mulched	19.8	20.4	20.2
Compost not amended	19.7	21.0	19.9

DISCUSSION AND CONCLUSIONS

The data of the present study show that the use of peat, cinders, or Haydite did not benefit the compost made from Genesee silt loam. While the composted soil did pack so tightly that water remained on the surface as long as 1 hour after watering, flower production was unaffected. Likewise, root growth was of a strikingly smaller volume in the unamended composted soil without affecting flower production.

The amendment materials altered the texture of the mixtures greatly. The mixtures appeared more porous than the original composted soil. They dried at widely different rates. The mixtures containing peat always looked and felt too wet to water. Florists commonly assume that this wet appearance indicates that watering is not needed. Feustel and Byers (1) showed that there was only a slight increase in the amount of water available to the plants from the use of 50 per cent peat by volume, although the waterholding capacity of the resulting mixture was increased 40 to 50 per cent.

The variations in flower production of greenhouse roses commonly reported for plants grown in different soil mixtures in which a uniform fertility was maintained probably were due to previously unrecognized differences in the available soil water. In the present study, soil moisture was maintained at a uniform capillary tension.

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Some Factors Affecting Flowering of Daphne Cneorum

By Joseph E. Howland,[1] *Cornell University, Ithaca, N. Y.*

Daphne Cneorum is an attractive pot plant for Easter. It forces easily at 50 degrees F, but many florists have trouble forcing it. The problems are timing the crop, blindness, and uneven development of the flowers in the cluster. A disease which causes the leaves to fall and the twigs to die back from the tips is also common. This is usually mistaken for simple windburn winter-injury and is present in most plants older than 2 years (1). It appears to cause trouble only when the plant is weakened by some other factor and plants may lose nearly every leaf soon after forcing is started.

Daphne Cneorum plants "prepared for forcing" are plants 2 years or more old which have been sheared back to within a few inches of the ground during the last summer. This shearing served a triple purpose: (1) removed all old leaves — and any disease organisms they might carry; (2) produced a compact plant of uniform height; (3) caused flower bud differentiation to occur at the same time on all branches.

Experimental Materials and Methods

Fifty plants of the 9 to 12 inch diameter size were received from the grower on December 8, 1942. 25 plants were "prepared for forcing" (sheared September 9, 1942). The other plants were unsheared. All plants had 50 or more flower buds. The size of the buds on the "prepared" plants was uniform, but the buds on the unsheared plants were of many sizes.

The plants had been dug and potted in Cloverset pots in the fall. Storage was in an unheated shed until the plants were shipped by the grower. *Daphne Cneorum* is not injured by ordinary winter temperatures and no attempt was made to prevent freezing during this storage period or during shipping.

All plants were stored in a refrigerator at 40 degrees F from December 8, 1942 until they were forced. Temperatures of 45, 60, 70 and 75 degrees F (10 degrees higher in daytime in each case) were used for forcing. The treatments started on December 13, January 14, February 14, March 14, and March 28. Two "prepared" plants plus one unsheared plant were used in each of the lots forced at 45 and 60 degrees F, and one "prepared" plus two unsheared plants were used in each lot at 70 degrees F. Five unsheared plants were forced December 13 at 75 degrees F in a glass case where high humidity was

[1]The author has enjoyed the active cooperation of many nurserymen and florists during the past 5 years on this study. Special mention should be made of Adams Nursery, Inc., Springfield, Mass. who donated the plants used in the 1942–43 trials.

The project was started at Rhode Island State College in 1939, moved to Michigan State College in 1940, and moved to Cornell University in 1942.

The author takes pleasure in acknowledging the assistance of Miss Frances Helen Elliott in the bud differentiation studies. Assistance in the routine of the experiments was given by Fred F. Horton, Jewett Hamilton, Ralph Christie and Eugene S. Johnston.

maintained by frequently syringing the plants.

The total number of buds present on each plant, when received from the grower, was recorded, as was the number of buds which failed to open by May 1.

All plants were inspected weekly. A plant was considered in flower when approximately 30 flower buds had opened. To be commercially salable as flowering plants, the 9 to 12 inch diameter plants should have approximately 50 flower clusters, but to have used fifty as the critical number in the present experiment would have been unwise because some of the unsheared plants had a total of only 50 to 60 buds.

Only "prepared" plants were used in the 1943 to 1944 season. 50 plants, 9 to 12 inches in diameter, were received from the grower on December 18, 1943. Four plants were used in each treatment. The plants were stored at low temperature from December 18 until they were forced. 40 degrees F storage under mechanical refrigeration was compared with storage in a nursery pithouse storage maintained at approximately 40 degrees F (varied from 35 to 50 degrees F).

Experimental Data

Less time was needed to force the plants later in the season. They also forced faster at high temperatures (see Tables I and II).

TABLE I—Forcing Time Required at Various Times in the Spring, 1943

Forcing Begun	Temperature Used for Forcing (Degrees F)		
	45 (Weeks)	60 (Weeks)	70 (Weeks)
Dec 13	16	8	5½
Jan 14	9	6	3½
Feb 14	8	5	3
Mar 14	6	4	3
Mar 28	4	2	1½

TABLE II—Forcing Time Required at Various Times in the Spring, 1944

Forcing Begun	No Storage	Forced at 48 Degrees F		Forced at 60 Degrees F	
		Stored at 40 Degrees F (Weeks)	Pithouse Storage (Weeks)	Stored at 40 Degrees F (Weeks)	Pithouse Storage (Weeks)
Dec 18	14 weeks	–	–	—	–
Jan 15	—	6	6	4½	6
Feb 23	—	6	–	4	5
Mar 9	—	5	6	—	–
Mar 16	—	4	5	—	–

It was not profitable to attempt forcing before mid-February because only a small percentage of the flower buds opened on plants where forcing was started earlier.

About 10 per cent of the buds produced flowers when forcing started on December 13, regardless of the temperature used. Only 40 per cent of the buds opened when forcing started on January 14 unless the forcing temperature was 45 degrees F. At this temperature, the plants

TABLE III—EFFECT OF TIME FORCING STARTED ON PERCENTAGE OF FLOWER BUDS WHICH OPENED

Forcing Begun	Temperature Used for Forcing (Degrees F)			
	45 (Per Cent)	60 (Per Cent)	70 (Per Cent)	75 (Per Cent)
Dec 13	18	10	10	12
Jan 14	58	40	44	—
Feb 14	—	89	100	—
Mar 14	93	70	70	—
Mar 28	100	100	—	—

flowered at the same time as these which were forced at 60 degrees F starting February 14. A greater percentage of the buds opened on these latter plants (Table III).

Flower buds which failed to open when the particular forcing conditions caused flowering of the plant rarely opened at a later date. Unpublished experiments made by the author several years ago showed that *Daphne Cneorum* produced flower buds at the high temperature of summer, but that a period of low temperature storage was required to complete the development of these buds so that they would open. In this they resemble the response of azaleas reported by Skinner (2).

Differentiation and bud development of the "prepared" plants was not complete when the plants were received from the grower in mid-December, although the buds were ⅛ inch or more in diameter at that time. Microscopic study of these buds showed that the florets differentiated and developed as umbels, with the outer florets occasionally fully matured before the center florets were more than differentiated. Incomplete differentiation or development appear to be the reasons plants sometimes produce flower clusters in which only a few of the individual florets open as flowers. A plant subjected to high temperatures only long enough to differentiate part of the florets in the cluster and then subjected to a low temperature at which these differentiated florets developed, did not produce the normal number of florets to fill the flower cluster. Stamens were well differentiated before the initial differentiation of the pistil occurred.

The flowers withered within 4 days after opening in the 70 degrees F treatments, but the dropping of the flowers as reported by Ivar Ringdahl, a florist of Rome, New York, for this temperature was never observed. Forcing temperature did control the flower color, however. Temperatures below 70 degrees produced normal depth of pink color, 70 degrees produced a pale pink color, and 75 degrees at high humidity produced white flowers.

DISCUSSION

The use of a 40 degree F refrigerator was the most satisfactory method for providing a low temperature treatment to develop the flower buds. Coldframe storage had proved unsatisfactory in preliminary studies because it was difficult to secure sufficient ventilation to prevent rapid spread of disease. The temperature variation in the nursery-type pithouse storage was too great to make use of it satis-

factorily. Leaf drop during storage in the 40 degree F refrigerator was found in preliminary experiments to be insignificant, both in the dark and under artificial light.

Blind plants which florists have reported among those purchased as "prepared for forcing" apparently were those plants in which bud development was incomplete at the time of forcing. Good specimens for forcing were those which were compact, symmetrical and uniformly covered with flower buds which were uniformly and completely developed when forcing began. Plants under 9-inch diameter required a minimum of 30 opened flower-clusters to be salable; the 9- to 12-inch diameter plants, a minimum of 50.

Plants which were sheared uniformly and at the correct time flowered uniformly. Flower buds on branches too low to be removed when the plants were sheared, flowered weeks before the new crop of buds. The irregularity in the time of flowering of plants which were not sheared made them worthless as commercial pot plants.

Timing of the crop must be accurate, since the flowers remain attractive only a few days. Storage of the plants at 40 degrees F in the dark when they were in full bloom caused a loss of the fragrance after 2 to 3 days. Some nurserymen have recommended storage for 12 to 24 hours in a cold room before delivery "to improve color and fragrance".

The plants should be kept well-watered at all times, but frequent syringing did not increase earliness of flowering.

Plants sheared late in the season (September 12) apparently had so little stored food in them that they were unable to maintain chlorophyll production under the low light intensities prevailing during the forcing period, hence became an unattractive yellow-green in color soon after flowering. Customers who expected to grow the plant as a houseplant until conditions were favorable for planting it in the garden as a permanent evergreen shrub could be expected to complain about this condition.

Summary

Daphne Cneorum forced February 15 at 50 to 55 degrees F flowered in 8 weeks. Only plants "prepared for forcing" were successful. Flower buds were formed at high temperature, but required a period of low temperature to complete the development. Plants forced slower early in the season, or at low temperatures. Blindness occurred if the buds were incompletely developed. Timing the crop must be accurate because the flowers remained attractive only a few days. Forcing temperature controlled flower color. Temperatures under 60 degrees F gave the best color.

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The Rate of Photosynthesis of Greenhouse Roses

By JOSEPH E. HOWLAND,[1] *Cornell University, Ithaca, N. Y.*

THE author recently reported (8) a 7 to 11 per cent increase in the keeping time of cut roses. He associated this with the afternoon increase in carbohydrate content of the leaves on the cut flowers.

The available literature did not contain data on the differences to be expected in the carbohydrate content of rose leaves, morning versus afternoon. Likewise, data indicating relative efficiency for use of light of various intensities were not available, although Post and Howland (12) have shown that monthly differences in flower production of greenhouse roses correlated with monthly differences in light intensity.

The present experiment was designed to measure net increases in dry weight during the day and decreases during the night in the leaves of Peter's Briarcliff and Better Times roses under commercial greenhouse conditions.

Preliminary studies by Elliott (5) indicated that greenhouse roses were much more efficient in food synthesis at low light intensities than commonly believed by florists. Leaves on the variety Better Times were found to produce more carbohydrates during a snowstorm on March 29, 1944 than they consumed in respiration during the 24 hours from 8 a. m. March 29 to 8 a. m. March 30. Only 7,272 foot candle hours of light were received ruing the day, approximately 25 per cent of the daily average for the week. Miss Elliott measured photosynthesis by the twin-leaflet method as the change in dry weight. Translocation from test leaflets were prevented by scalding the rachis below the test leaflets and removing the terminal leaflet. The increase in dry weight in the 24 hours averaged 3.86 per cent in "recently matured" leaves. Older leaves, *i. e.* those on the stem below the place of origin of the current flowering shoot, averaged a 4.74 per cent increase. Both of these gains were statistically significant at the 5 per cent level.

Kaiser (17) noticed that chrysanthemums cut in the afternoon lasted longer than those cut in the morning. He suggested that the difference was due to the greater carbohydrate content of flowers cut in the afternoon. He made no quantitative measurements of photosynthesis.

Kiplinger (9) concluded from preliminary experiments that the rate of photosynthesis in leaves of flowering shoots of greenhouse roses was two to three times the rate in leaves of non-flowering shoots. Data were not presented. Kiplinger thought that leaves on non-flowering basal shoots carried on practically no photosynthesis. Rate of synthesis was assumed to decrease with age of leaf. Two thousand foot candles of light was considered the optimum intensity for greenhouse roses.

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[1]Acknowledgment is made to Frances H. Elliott for permission to use unpublished data, and to Miss Elliott, Dr. O. F. Curtis, Dr. Kenneth Post, and O. C. Compton for valuable suggestions on methods. Routine work was simplified by the efficiency of Betty Beyer and Iva E. Piper. Fred F. Horton was rose grower.

Denny (4) measured dry weight changes in leaves of *Salvia* during a sunny day in April. Between 5:30 a. m. and 3:30 p. m., tip leaves increased 42 per cent in dry weight. Older leaves increased 38 per cent in dry weight in the same time.

Fossum (6) used the gas exchange technique to compare carbon dioxide absorption of greenhouse roses as affected by various spray materials. He used six plants per treatment, and was limited by his equipment to making determinations on 12 leaves at any one time. Measurements were made for a 3 hour period at various times during January through April. Similar studies were made by Kiplinger and Laurie (10) and Laurie and Witt (11).

Materials and Methods

Photosynthesis was measured as the change in dry weight of matched leaflets. Accuracy of the method has been found adequate in extensive tests by Curtis and his students (7). Denny (4) found the method particularly useful for roses.

Measurements were made in a commercial type greenhouse planting at Ithaca, New York. There were 768 plants of the variety Peter's Briarcliff and 576 plants of the variety Better Times, the former in their second year of production and the latter in their third year.

All plants were syringed, *i. e.* sprayed at high pressure with water, once a week for control of red spider mites. Plants were sprayed with Fermate (1 pound per 100 gallons of water) immediately after being springed. Vatsol K was used as the spreader. Occasionally, the plants were sprayed with malachite green to control mildew. No measurements of dry weight changes were made when mildew was visible, or for at least 2 weeks after application of malachite green. Fossum (6) and others have found the reduction in the rate of carbon dioxide absorption following use of most common spray materials continued for 10 days or less.

The experiment was limited to duplicate leaflets in the three uppermost "mature" five leaflet leaves on shoots where the flower bud "showed color." Such flower buds normally were ready to be cut within 2 to 4 days. This stage was selected because the measurement would reflect conditions in the leaves at a time when translocation from them would be at a high rate. It was found impractical to use the 24 hour period just prior to the time the flower was cut because the rate of opening in the last day depended mainly on the temperature. The restriction used in the present study resulted, however, in the use of leaves and shoots at a uniform stage of physiological development.

Leaflets were removed at 7 a. m. and 6:30 p. m. (E. W. T.) during June through September, and at 8 a. m. and 6 p. m. during the remainder of the year. They were dried in a forced draft oven at 65 degrees C. Measurements usually were made from evening to morning, and from one evening to the next evening. 25 leaflets were used for each period. Occasionally, measurements were made from morning to evening, and from one morning to the following morning.

Only leaflets fully exposed to the sunlight were used.

The light intensity outside the greenhouse was measured by an automatic light recorder employing a Weston light meter (13). The air temperature in the greenhouse was 58 to 60 degrees F at night and 68 degrees F and up in the day, except when the outdoor temperature was higher (June through September). Leaf temperatures probably exceeded air temperatures by 5 to 10 degrees F during the day, and may have been several degrees below air temperature at night, because of absorption and loss respectively of radiant energy, as described by Curtis (1).

The greenhouse was ventilated according to commercial practices. No attempt was made to alter relative humidity or the carbon dioxide content of the air. Manure mulches were never used. The soil was maintained at a soil moisture capillary tension of less than 8 cm of mercury, as measured by soil tensiometers. Shading materials were never used on the glass.

Normal translocation from the leaf was possible at all times during the trials. Dry weight changes thus were the net effect of photosynthesis, respiration, and translocation. The net gain in dry weight represented the daily gain available for renewal growth of the plant as the flowers were removed, assuming that a similar gain occurred in the leaves lower on the plants. Miss Elliott's data, also that of Rikhter, Sukhorukov, and Ostapenko (14, 15, 16) indicate that this probably was true.

Miss Elliott found old leaves just as efficient in food synthesis as "recently matured" leaves. True, light intensity undoubtedly was higher on leaves near the apex or flowering stems, but translocation from these apex leaves to the opening flower bud likely was at an accelerated rate. In addition, while much of the food translocated from the test leaves probably was used in root growth, some of it likely was used in renewal growth of the top of the plant.

Rikhter, Sukhorukov, and Ostapenko found that a definite rate of photosynthesis was established rather early in the life of the leaves. Processes occurring later in the plant affected this rate only slightly. There was no correlation between stage of development and rate of photosynthesis. Plants studied were sunflower, corn, cucumber, tobacco, soybean, kok-saghyz, and beans.

The measurements presented are thus considered as representative for the plant.

Results

Net dry weight changes for the day and for the night are reported in Table I and II for 25 dates for Peter's Briarcliff and for 21 dates for Better Times. Dates reported are July, August, September, and December, 1944 and March, April, and June, 1945. Light intensity is reported for the test day and the 2 previous days.

Fig. 1, 2, and 3 show graphically the daily changes through 3 to 5 day periods in August, December, and April.

Occasionally, both pairs of leaflets on a five-leaflet leaf were found to be duplicates. The differential for the dry weight changes in the two pairs of leaflets from a single leaf was large and not consistently in one direction within a variety or between varieties. The average net

TABLE I—Dry Weight Changes in Leaves of Peter's Briarcliff at Different Times During the Year

Year of 1944	Foot Candle Hours Per Day	Per Cent Dry Weight Change			Per Cent Net Dry Weight Change Per 10,000 Foot Candle Hours	Per Cent Dry Weight Gain in Day Per 10,000 Foot Candle Hours
		Night	Day	Net		
Jul 16	62,057	—	—	—	—	—
17	80,365	—	—	—	—	—
18	70,838	-2.22	+11.09	+8.87	1.25	1.57
29	73,838	—	—	—	—	—
30	63,839	—	—	—	—	—
31	73,284	-5.93	+8.82	+2.89	0.39	1.20
Aug 1	62,039	-5.31	+12.41	+7.10	1.14	2.00
2	61,730	-3.31	+11.48	+8.17	1.32	1.86
3	72,656	-2.87	+ 8.61	+5.74	0.79	1.19
Sep 3	58,776	—	—	—	—	—
4	36,542	—	—	—	—	—
5	29,970	-3.02	+ 7.42	+4.40	1.47	2.48
10	62,957	—	—	—	—	—
11	50,413	—	—	—	—	—
12	25,801	-4.14*	+ 6.25*	+2.11	0.82	2.42
13	14,041	-4.41	—	—	—	—
14	26,025	-5.89	+10.35	+4.46	1.71	3.98
19	22,252	—	—	—	—	—
20	51,549	—	—	—	—	—
21	37,205	-6.73	+ 8.76	+2.03	0.55	2.35
24	46,623	—	—	—	—	—
25	38,142	—	—	—	—	—
26	28,897	-3.39	+ 5.00*	+1.61	0.56	1.73
27	41,005	-5.33	+ 7.54*	+2.21	0.54	1.84
Dec 10	25,561	—	—	—	—	—
11	16,662	—	—	—	—	—
12	3,609	-6.50	+ 6.05	-0.45	—	1.68
13	5,018	-5.48	-0.51*	-5.99	—	—
14	24,670	-3.41	+6.70	+3.29	1.33	2.72
15	25,061	-1.70	+7.50	+5.80	2.31	2.99
1945						
Feb 26	15,680	—	—	—	—	—
27	13,462	—	—	—	—	—
28	34,097	—	—	+4.48	1.31	—
Mar 1	40,341	-2.07	+ 2.09	+0.02	—	0.52
2	24,025	-1.28	+ 3.66	+2.58	0.99	1.52
3	40,732	+0.69*	+10.11	+9.42	2.31	2.48
Apr 1	48,995	—	—	—	—	—
2	13,590	—	—	—	—	—
3	12,517	-3.17	+3.48	+0.31	0.25	2.78
4	No rec'd	+3.11*	+13.45	+10.34	—	—
5	46,786	-6.27	+13.22	+6.95	1.49	2.83
6	61,657	-6.72	+11.25	+4.53	0.73	1.82
7	59,003	-8.59	+15.02	+6.43	1.09	2.55
8	57,694	-2.63	—	—	—	—
Jun 26	54,694	—	—	—	—	—
27	81,674	—	—	—	—	—
28	44,050	-2.60	+8.83	+6.23	1.41	2.00
29	45,541	-4.34	+8.97	+4.63	1.02	1.97
Grand average		-4.39	+8.30	+3.91	0.99	2.02
Grand average for days when both Peter's Briarcliff and Better Times were used		-4.02	+7.75	+3.73	0.93	1.99

*Livermore's modification of Student's formula was used on the data to compute significance expressed as odds. Only those data marked with an asterisk showed odds of less than 99:1.

change for 24 hours for eight pairs of leaflets of Peter's Briarcliff and for three pairs of leaflets of Better Times are reported in Table III.

Discussion

The greenhouse rose is surprisingly efficient in net food synthesis

TABLE II—DRY WEIGHT CHANGES IN LEAVES OF BETTER TIMES ROSES AT DIFFERENT TIMES DURING THE YEAR

Year of 1944	Foot Candle Hours Per Day	Per Cent Dry Weight Change			Per Cent Net Dry Weight Change Per 10,000 Foot Candle Hours	Per Cent Dry Weight Gain in Day Per 10,000 Foot Candle Hours
		Night	Day	Net		
Jul 16	62,057	—	—	—	—	—
17	80,365	—	—	—	—	—
18	70,838	-5.25	+11.15	+5.90	0.83	1.57
Aug 2	61,730	—	—	—	—	—
3	72,656	—	—	—	—	—
4	54,113	-3.92	+8.34	+4.42	0.82	1.54
5	52,031	-4.36	+10.10	+5.74	1.10	1.94
Sep 3	58,776	—	—	—	—	—
4	36,542	—	—	—	—	—
5	29,970	-7.13	+7.48	+0.35	0.12	2.50
6	48,686	—	—	—	—	—
7	43,005	-4.48	+8.17	+3.69	0.86	1.90
8	14,462	-4.86	—	—	—	—
19	22,252	—	—	—	—	—
20	51,549	—	—	—	—	—
21	37,205	-6.80	+10.92	+4.12	1.11	2.94
24	46,623	—	—	—	—	—
25	38,142	—	—	—	—	—
26	28,897	-4.88	+7.41	+2.53	0.88	2.56
27	41,005	-7.90	+8.98*	+1.08	0.26	2.19
28	10,535	-8.84	-0.09*	-8.93	—	—
Dec 10	25,561	—	—	—	—	—
11	16,662	—	—	—	—	—
12	3,609	-6.69	+6.25	-0.44	—	1.73
13	5,018	-3.29	+4.38	+1.09	0.22	0.87
14	24,670	-2.54	+12.12	+9.58	3.88	4.91
15	25,061	-4.71	+8.89	+4.18	1.67	3.55
			1945			
Feb 26	15,680	—	—	—	—	—
27	13,462	—	—	—	—	—
28	34,097	—	—	+10.97	3.22	—
Mar 1	40,341	-10.91	+18.83	+7.92	1.96	4.67
2	24,025	-4.64	+5.27	+0.63	1.26	2.19
3	40,732	+1.49*	+9.65	+9.65	2.37	2.37
Apr 1	48,995	—	—	—	—	—
2	13,590	—	—	—	—	—
3	12,517	-5.17	+7.01	+1.84	1.47	5.60
4	No rec'd	-2.30	+5.85	+3.55	—	—
5	46,786	-3.83	+11.02	+7.19	1.54	2.36
6	61,657	-4.42	+15.42	+11.00	1.78	2.50
7	59,003	-12.06	+14.69	+2.63	0.45	2.49
Jun 27	81,674	—	—	—	—	—
28	44,050	—	—	—	—	—
29	45,541	—	—	—	—	—
Grand average		-5.26	+9.14	+3.88	1.18	2.52
Grand average for days when both Peter's Briarcliff and Better Times were used		-5.35	+9.72	+4.37	1.18	2.81

*Livermore's modification of Student's formula was used on the data to compute significance expressed as odds. Only those data marked with an asterisk showed odds of less than 99:1.

over a wide range of light intensities. Net dry weight gains for 24 hours were produced on all test days when the light was above 11,000 foot candle hours, even though translocation from the test leaflets was not prevented.

The method used for measuring synthesis precludes the possibility of calculating the respiration/synthesis quotient. It is obvious that a net change in dry matter for any 24 hour period reflects the light, temperature, and growth conditions of the plant during several preceding

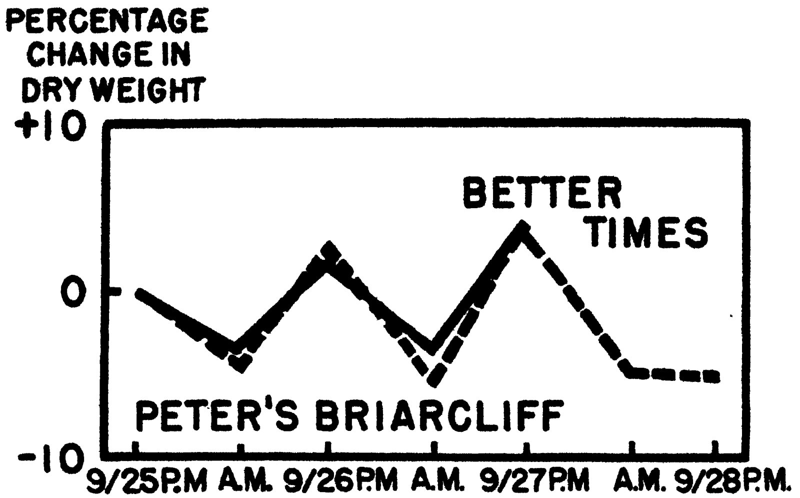

FIG. 1. Percentage change in dry weight of rose leaflets, September 25 to 28, 1944.

days as well as on the test day. Accordingly, reported decreases in dry weight of leaves on September 28 at 10,535 foot candle hours of light, or on December 12 and 13 at 3,609 and 5,018 foot candle hours respectively, do not indicate *per se* that rose leaves are unable at these light intensities to synthesize sufficient food for their own respiration.

The grand average net changes in dry weight for the days when both varieties were used indicate for Better Times a 33 per cent greater loss at night, 25 per cent greater gain during the day, and 17 per cent greater net gain in 24 hours. Efficiency in use of light (per foot candle hour) was 41 per cent higher for Better Times.

In preliminary trials on "mature" leaves of Red Radiance, a garden rose, made outdoors at Ithaca on September 6, 1944 (48,686 foot candle hours of light), a net dry weight gain of 3.38 per cent was found for the 24 hour period. Data for greenhouse roses are not available for this date, but on September 5 (29,970 foot candle hour) there was a net gain of 4.40 per cent by Peter's Briarcliff and 0.35 per cent by Better Times. The latter variety gained 3.69 per cent on September 7 (43,005 foot candle hours).

The data are insufficient to warrant strict comparisons between varieties for efficiency of food synthesis. Peter's Briarcliff was grown in the three southerly benches in an east-west greenhouse: Better Times was grown in the three northerly benches in the same greenhouse. Since the Better Times plants consequently received appreciably less light, the indicated greater efficiency for the use of light by them would indicate a considerable difference in efficiency. However, the Peter's Briarcliff plants averaged 40 to 45 flowers per plant for the year, about five flowers more than were produced by the Better Times plants. It should also be noted that in September (Fig. 1) there was no difference in the net gains of the two varieties, and in April (Fig.

TABLE III—AVERAGE NET CHANGE IN DRY WEIGHT OF PAIRED LEAFLETS ON THE SAME 5-LEAFLET LEAF OF GREENHOUSE ROSES

Variety of Rose	Position of Leaflets (Per Cent)	
	Apex Pair	Basal Pair
Peter's Briarcliff	+3.22	+9.48
Better Times	+6.93	+6.22

3) Peter's Briarcliff made a 39 per cent larger gain in dry weight in 5½ days than did Better Times.

While a net gain in dry weight of 18.8 per cent during the day (Better Times on March 1, 1945), and of 10.3 per cent for the 24 hours (Peter's Briarcliff on April 4, 1945) were unexpectedly large, they are not out of line with data on other plants as recently reviewed by Curtis (5) and others.

Curtis (2) reported an average increase of 19 per cent in total dry weight for alfalfa hay cut in the late afternoon instead of in the early morning. He later (3) indicated that a 10 per cent average net gain per day probably was common for hay plants.

Recalculation of the extensive data of Grimm (7) to express changes as a percentage of dry weight, shows that his privet *(Ligustrum)* plants averaged a 6.38 per cent gain from 8 a. m. to 4 p. m. and a 4.82 per cent loss from 8 p. m. to 5 a. m.

The grand average daily gain reported in the present paper, namely 8.3 per cent for Peter's Briarcliff and 9.1 per cent for Better Times, and the average daily net gain for 24 hours of 3.9 per cent for both varieties, are well within the ranges reported for other crops.

If large enough samples are used and the data treated statistically, the twin-leaflet method is well-adapted to use on roses. There seemed

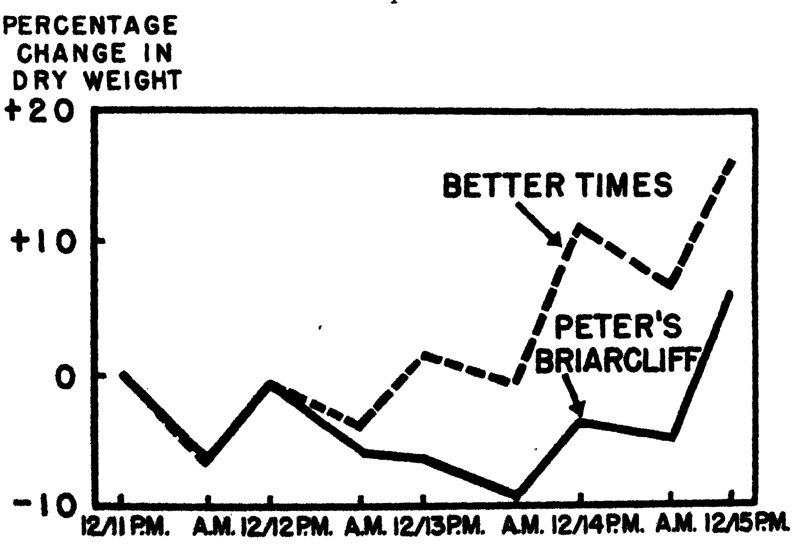

FIG. 2. Percentage change in dry weight of rose leaflets, December 11–15, 1944.

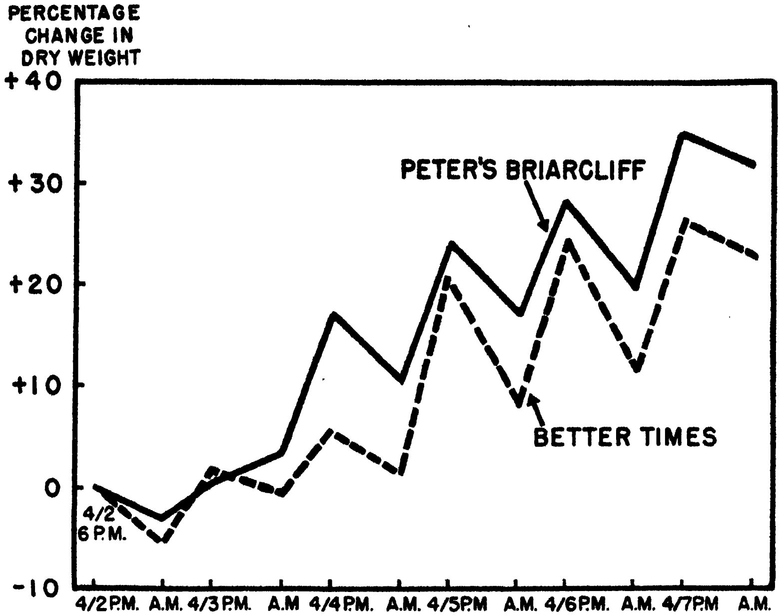

FIG. 3. Percentage change in dry weight of rose leaflets, April 2–8, 1945.

to be no particular value in limiting choice of leaflets to either the upper or lower pair of leaflets on the 5-leaflet leaves.

SUMMARY

Net changes in dry weight of rose leaves during the day and at night for the varieties Peter's Briarcliff and Better Times were measured at various times during the year by the twin-leaflet method. Translocation of carbohydrates from the test leaves was not prevented.

The grand average daily gain due to photosynthesis was 8.3 per cent for Peter's Briarcliff and 9.1 per cent for Better Times. Average daily net gain for 24 hours was 3.9 per cent for both varieties.

The twin-leaflet method was well-adapted to roses. There was no particular advantage to limiting choice of leaflets to either the upper or lower pair of leaflets in the five-leaflet leaves.

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A Comparison of Production of Greenhouse Roses Grown on Three Rootstocks

By KENNETH POST and JOSEPH E. HOWLAND,[1] *Cornell University, Ithaca, N. Y.*

Rosa Manetti has been nearly the universal choice of understock for greenhouse roses in the United States. Various other species have been introduced periodically for the past 50 years by plant propagators interested in developing an American source of understocks, but none of these species have been acceptable to the florists. The usual objection is that other stocks become dormant in mid winter. The small amount of experimental data does not support this view. Weinard and Dorner (1) found growth and production of greenhouse roses equally satisfactory on *Rose odorata and R. manetti.* However, the practical experience of Jackson & Perkins, large conmerical rose propagators, shows *Rosa manetti* to be the ideal understock for greenhouse roses.

MATERIALS AND METHODS

During the past 3 years, Briarcliff roses budded on 3 understocks were grown at Ithaca to compare growth and production.

The standard understock of greenhouse roses, *Rosa manetti,* was compared with *Rosa multiflora Welchi* and a hybrid supplied by the late Dr. J. C. Ratsek of the Texas Agricultural Experiment Station and identified by him as "R. 620037 cross."

A waterproof concrete bench was used. Each plot was 3 feet wide and 10 or 11 feet long, and contained 30 or 33 plants. There were two replications of each treatment. Texas-grown, started-eye Briarcliff plants, donated for the experiment by the late Dr. Ratsek, were planted immediately in 5-inch pots when received on March 26, 1942. They were transplanted into the bench on June 14, 1942. Production began in September, and the first year data included October 1 through May 26, 1943 (8 months). The plants were dried off in the usual commercial manner, beginning on May 26, 1943 and then cut back. Production began again in August and the plants then were maintained in continuous production until they were discarded on February 28, 1945. The second year data include August 1 through June 30, 1944 (11 months) and the third year data include July 1, 1944 through February 28, 1945 (8 months).

No manure mulch was ever used on any plot. Soils were tested twice each month by the Spurway system. Nitrates were maintained at 25 to 100 ppm by applications of ammonium sulphate. The soil reaction (pH) was adjusted to pH 6.2 to 6.4 before planting. The pH remained between 6.0 and 6.7. The soil was a Genesee silt loam to which was added by volume 17 per cent cinders and 17 per cent peat after it had

[1]The project was established by John G. Seeley and conducted by him until July 1943. Joseph E. Howland has been in charge of the study since that time. Fred F. Horton has been the grower. The soil testing has been done by Iva E. Piper during 1944 and 1945. All work has been under the supervision of Dr. Kenneth Post.

been composted for 9 months with manure. Superphosphate was added to it at the rate of 5 pounds per 100 square feet of bench area before the crop was planted. The manure in the compost supplied enough potassium for the first year. In July, 1943, July, 1944, and February, 1945, an application of 4 pounds of complete fertilizer (5–10–5) per 100 square feet of bench area was made. These 3 applications of complete fertilizer were enough to keep the P test above 5 ppm and the K test above 20 ppm at all times.

All plots were surface watered at 8 cm capillary tension (measured with mercury tensiometers). In other experiments, the authors found that flower production of greenhouse roses was highest when the soil was kept as wet as possible without waterlogging it.

Flowers were cut each morning and the stems graded into lengths of 3 inches as is done by most commercial rose growers. For example, an 18 inch rose had a stem more than 18 inches long and less than 21 inches. Thus, the true average stem length of the 18 inch grade is 19½ inches. Accordingly, to determine the true average stem length in the present study, 1½ inches were added to the mean length as calculated by the 3 inch grade designations.

Results

None of the differences in flower production on the various rootstocks recorded in Table I are significant.

TABLE I — Effect of Rootstock on Flower Production of Peter's Briarcliff Roses

Rootstock	1942–43 (8 Months)	1943–44 (11 Months)	1944–45 (8 Months)	Total for 3 Years
R. Manetti	12.3	30.1	20.1	62.5
R. multiflora Welchi	12.9	27.2	18.2	58.3
R. 620087 cross	13.0	26.0	18.2	57.2
Least significant difference at 5 per cent level	1.9	10.5	5.5	—

Leaf drop was consistently much less severe on the plants growing on *Rosa Manetti*. Average stem length of the cutflowers, however, was not significantly different for any rootstock (Table II).

TABLE II — Effect of Rootstock on Average Stem Length of the Cut Flowers of Peter's Briarcliff Roses

Rootstock	Average Stem Length (Inches)		
	1942–43	1943–44	1944–45
R. manetti	19.7	21.3	17.8
R. multiflora Welchi	19.8	20.3	17.8
R. 620087 cross	18.9	20.5	17.6

Summary

There was no advantage in using either *Rosa multiflora* or a special Texas hybrid rose as rootstocks for Briarcliff as a greenhouse rose, when compared with the common understock, *Rosa manetti*. Flower

production and average stem length of the cut flowers was not significantly different for any of the three understocks. Possible differences in disease resistance was not a factor in the present study. At no time was there any tendency for any of the plants to enter a dormant condition in the winter. The noticeable differences in amount of leaf drop did not result in significant differences in production.

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Foliar Dieback of the Greenhouse Snapdragon *Antirrhinum Majus* and a Study of the Influence of Certain Environmental Factors Upon Flower Production and Quality

By JOSEPH E. HOWLAND,[1] *Cornell University, Ithaca, N. Y.*

FOLIAR dieback of the greenhouse snapdragon has been reported since 1930 in New York, Massachusetts, Connecticut, Michigan, Ohio, Illinois, and Colorado. It is widespread only in occasional years. When serious, it renders the crop completely unsalable. Varietal susceptibility has been observed to vary markedly.

Visible leaf injury in plants from seed sown in July occurs in late September on leaves which have recently reached full size. These leaves gradually dry back from the tip, often in a V-shape with the V pointed toward the base of the leaf. Injury is confined initially to leaves on the middle third of the stem. Often only one leaf on the plant is damaged. Development of the trouble may be highly erratic. Even when progress is rapid, leaf tissues die at an irregular rate, causing a characteristic banding on the dead area (Fig. 1). Sometimes dieback ceases completely for several days to several weeks. Plants are rarely killed, and by April usually outgrow the trouble.

The cause of foliar dieback is unknown. The condition has not been produced experimentally. Presence of a pathogen has never been found correlated with the trouble. Florists do not know in what years

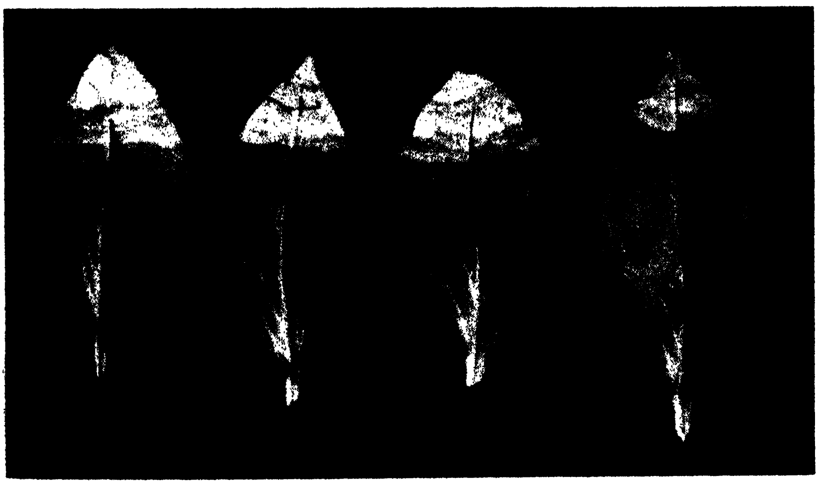

FIG. 1. Typical banding effect produced on leaves of greenhouse snapdragons affected by foliar dieback.

[1]The author wishes to acknowledge his indebtedness to Kenneth Post, Otis F. Curtis, and Richard Bradfield for advice and encouragement; to Frances Helen Elliott and Richard A. Carrigan for permission to use unpublished data; and to the 30 florists who cooperated in this work. Routine work was greatly simplified by the efficiency of Iva E. Piper, Fred F. Horton, Eugene S. Johnston, Katherine Barnes, and Jewett Hamilton.

the injury is likely to be severe, and are unable to check its spread once it does appear. Plant breeders are interested in developing a technique for testing the susceptibility of new varieties.

Severity of injury is rather uniform within a variety throughout the state in any one year, but varies in different years. This suggests that nutrition, soil moisture, or air temperature cannot be the primary factor initiating the trouble. Light intensity may vary considerably in different years, with the variation inclusive over a wide geographical area. Light intensity and the amount of water vapor present in the sky directly affect the temperature differential between leaves and the air. When the air temperature of the greenhouse is maintained uniform, the leaf temperature may vary considerably over a short period of time (5 degrees C within a few minutes) if there are clouds in the sky. Such temperature differentials cause significant increases in water loss by transpiration, hence a sudden temperature rise may cause a water deficit in the leaves.

LITERATURE

Wilson (8) described foliar dieback of snapdragon. He reported increases in nitrate-N concentration in the expressed sap of leaf and stem tissues of the variety Cheviot Maid Supreme and suggested that foliar dieback was due to excess nitrate-N accumulated during periods of low light intensity. Florists were advised to keep the soil nitrate-N at a low level.

Microscopic study of leaf sections by Miss Elliott (4) indicated that the cells collapsed in this order: lower mesophyll, upper mesophyll, and finally, palisade cells. This suggests that stomates are the region of initial injury.

Review of the literature revealed the common opinion that snapdragons should be grown in soil of low nutrient content and rarely should receive nitrogen fertilizers. Temperatures of 48 to 52 degrees F were thought best. Growers were advised to water sparingly. Laurie and Mann (5), however, concluded that production was best when the crop was watered heavily, *i. e.* ½ gallon per square foot of bench area. Only Laurie and Mann presented data.

EXPERIMENTAL METHODS AND DATA

Experiments of four general types are reported here for the 1943–44 and 1944–45 seasons: (a) Influence of nitrogen and potassium nutrition, soil reaction (pH), soil type, soil moisture, daylength, light intensity, and temperature upon foliar dieback, flower production and quality, and nitrate-N content of leaves; and (b) effect of root injury on occurrence of foliar dieback.

Influence of Nitrogen and Potassium Nutrition, Soil Reaction (pH), Soil Type, Soil Moisture, Daylength, Light Intensity, and Temperature:—Snapdragons were grown at Ithaca in a factorial experiment which varied nitrogen and potassium nutrition, daylength, light intensity, and air temperature as follows:

Nutrition—$(NH_4)_2SO_4$ versus KNO_3 versus KCl versus no added fertilizer

Daylength—normal day versus 4 hours added light per day
Light intensity—normal versus approximately 50 per cent
Air temperature—night temperatures of 50 degrees versus 60 dedegrees versus 70 degrees F. (10 degrees F higher during the day in each case.)

In addition, the influence of the following factors was studied at the 50 degrees temperature:

Nutrition—$Ca(NO_3)_2$ versus $NaNO_3$ versus $NaNO_2$ versus tankage
Soil reaction—pH 5 versus pH 7
Soil type—1:1:1 versus 1:1:0 versus 1:0:0 soil-sand-peat mixtures
Soil moisture—3 cm Hg capillary tension versus 25 cm.

In 1943–44, the major part of the planting was of the variety Cheviot Maid Supreme, a variety previously observed to be very susceptible to foliar dieback. Seeds were sown in early August, seedlings potted in 2¼-inch pots on August 25 to 30, and the plants benched at 7½ by 7½ inches on October 1 to 15. Each plot contained 10 or more plants. Other varieties included were Afterglow, White Wonder, Super White, Super Pink, Jersey Maid, and Jersey Gold. A total of 1771 plants were grown. Commercial care was given in all cultural operations. The soil used was a Dunkirk very fine sandy loam.

Fertilizers were applied for "high" treatments on November 24, December 10, December 21, January 7, January 17, and March 11. No fertilizer was used on the "low" fertilization plots. All soils were tested twice monthly by a modified Spurway system (7).

The following materials were used: $Ca(NO_3)_2$, $NaNO_3$, KNO_3, $(NH_4)_2SO_4$, tankage, $NaNO_2$, KCl, $Ca(OH)_2$, and $Al_2(SO_4)_3$. Application of the nitrogen fertilizer was at the rate of 1 pound per 100 square feet of bench area except for $NaNO_2$ which was used at $^1/_{10}$ this rate.

The potassium fertilizer, the $Ca(OH)_2$ and the $Al_2(SO_4)_3$ were used at the rate of 2 pounds per 100 square feet of bench area.

Long-day plots were lighted from 7 p. m. to 11 p. m. (Eastern war time) daily from October 15 to March 1 by 25 watt bulbs suspended 2 to 3 feet above the plants and about 5 feet apart.

Reduced light intensity was obtained by complete enclosure of the plot in a frame covered with a single thickness of cheesecloth. This reduced the light intensity to approximately 60 per cent of normal, as measured with a Weston light meter.

Surface watering was used on all plots except those used in the soil moisture study. In the latter, water was injected when the soil tensiometer (7) indicated the desired capillary tension was exceeded. Only enough water was added to lower the tension to the desired level.

The plants were inspected every 7 to 10 days for visible sign of foliar dieback until the last crop of flowers were cut in late May.

A spectroscopic[2] comparison of injured versus normal leaves

[2]The author wishes to express his appreciation to R. A. Carrigan and to Thomas Erwin, both of the Florida Agricultural Experiment Station, for making this analysis.

TABLE I—Spectroscopic Data for Injured Versus Normal Leaves of Cheviot Maid Supreme Snapdragons, Expressed as Per Cent of the Ash (December, 1943)

Element	Per Cent in Injured	Per Cent in Normal
Lead	0.05	0.001
Barium	0.01	0.001
Boron	0.05	0.01
Aluminum	0.1	0.03
Strontium	0.01	0.005
Iron	0.1	0.05
Zinc	0.1	0.06
Manganese	0.1	0.1
Copper	0.01	0.01
Chromium	0.001	0.001
Molybdenum	0.001	0.001

showed an increase in the concentration of certain elements (Table I). These leaves were of the same physiological age and were obtained from plants of the same plots.

Table II contains similar data for three varieties in the 1944–45 crop.

TABLE II—Spectrographic Data for Injured Versus Normal Leaves of Three Varieties of Snapdragons, Expressed as Per Cent of the Ash. (December, 1944)

Element	Koester's White		Cheviot Maid Supreme		Afterglow	
	Per Cent Injured	Per Cent Normal	Per Cent Injured	Per Cent Normal	Per Cent Injured	Per Cent Normal
Lead	0.1	0.1	0.1	0.1	0.1	0.03
Barium	0.005	0.005	0.01	0.01	0.01	0.01
Boron	0.03	0.03	0.05	0.05	0.03	0.03
Aluminum	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
Strontium	0.005	0.005	0.01	0.01	0.01	0.05
Iron	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
Manganese	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
Copper	0.01	0.05	0.01	0.01	0.01	0.01
Chromium	*N.D.	N.D.	<0.001	<0.001	N.D.	<0.001
Molybdenum	0.001	0.001	N.D.	N.D.	N.D.	N.D.
Titanium	0.01	0.01	0.01	0.03	0.01	0.05
Nickel	0.001	0.005	0.003	0.003	0.01	0.001

*N.D.—not detected.

Lead arsenate sprays are used on snapdragons by some florists as insecticides, but the experimental plantings received only "Multicide," a non-lead insecticide.

The following elements, if present, occurred in such low concentrations that they could not be detected in either year by the procedure used: antimony, arsenic, beryllium, bismuth, cadmium, cesium, cobalt, germanium, gold, indium, lanthanum, lithium, mercury, silver, thallium, tungsten, vanadium, yttrium, and zirconium.

In 1944–45, the plots contained 10 plants each of five varieties previously observed to differ in their susceptibility to foliar dieback. A total of 2710 plants were grown. These varieties were White Wonder, Koester's White, Cheviot Maid Supreme, Afterglow, and Maryland Pink.

Seeds were sown on July 6, the seedlings potted in 2¼-inch pots on July 31, and the plants benched at 7½ by 7½ inches on August 24 to 30.

The soil was a shredded, 4-month-old compost of Genesee silt loam sod and manure. Washed, native bank sand and commercial baled sphagnum peat were used in 1 : 1 : 1, and 1 : 1 : 0 soil-sand-peat mixtures to study the influence of soil type. The muck (81.6 per cent organic matter[3]) was brought as its natural field moisture content from Elba, N. Y.[4]

Fertilizers were applied to the "high" treatments on September 21, October 5 and 25, November 13 and 22, and December 28 at the rate of 1 pound of fertilizer or lime per 100 square feet of bench area (2¼ pounds of $Al_2(SO_4)_3$). $NaNO_3$, $NaNO_2$, and tankage were not used. The soil in each plot was tested twice monthly.

Daylength was increased from October 4 to January 27 by the method used the previous year. Light intensity was decreased to about 40 per cent of normal from October 3 to January 27 by the use of a double thickness of cheesecloth to completely enclose the plots.

Development of Foliar Dieback:—Foliar dieback was uncommon in New York in 1943–44. The first leaf injury found at Ithaca was a leaftip injury on October 3 on several leaves of plants of the variety Cheviot Maid Supreme. No further injury was observed until November 24, when foliar dieback was found on six plants. Fifteen plants were found to be affected in the December 11 inspection, 18 on December 24, 20 on December 27, 21 on January 3, and 16 on March 7. There were 1771 plants in the experiment. Cheviot Maid Supreme and White Wonder were the only varieties affected.

Foliar dieback was relatively common in New York in the 1944–45 season, but it did not cause as much loss as in 1942–43. Plants of the variety White Wonder were found to be affected by a leaftip injury at Ithaca on August 24, 1944, but the banding characteristic of foliar dieback was not present in the damaged leaf areas. The seed had been sown June 1.

The first foliar dieback of unquestionable identity was found at Ithaca on October 5 on seven plants of the variety Koester's White. Four days later 31 plants were found to be affected. Foliar dieback developed rapidly during the next 2 weeks to affect a large number of plants, although progress back through the leaf blade was very slow. No petiole or stem injury was found.

Development of the injury appeared to stop about October 25, but was resumed a week later. Further development was rapid. By November 10, newly injured areas were visible as extensions of previously damaged areas and as damage in previously uninjured leaves.

Careful inspection on December 8, 1944, of every plant in the experiment of 2710 plants showed that foliar dieback was present in every variety in every plot. Only an occasional plant was completely free of injury. Incidence was characteristic of the variety and independent of the plot treatment. Damage became severe, completely ruining commercial value in the variety Koester's White and rendering

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[3]Determination of the organic content was made by E. V. Staker, Department of Agronomy, Cornell University.

[4]The muck was donated by William Stewart, Elba, N. Y., through the courtesy of Robert Kunkel, Department of Vegetable Crops, Cornell University.

unsalable over one half of the Cheviot Maid Supreme crop. Plants of the varieties Afterglow and White Wonder were considerably less susceptible to foliar dieback than were plants of the variety Maryland Pink.

Development of injury seemed to be halted from January 9 to 14, then was resumed at a slower rate.

From mid-December until February 3, study was made of the occurrence of foliar dieback after the damaged leaf area was removed. Preliminary trials in 1943–44 indicated that such a removal would stop further development of the injury in the treated leaves. In the extensive 1944–45 trials, care was taken to remove at least ⅛-inch of uninjured tissue when the injured area was removed. Leaves in various stages of the injury were used.

It was soon apparent that removal of part or all of the affected area had no predictable effect on occurrence of further injury.

Obviously, susceptibility to foliar dieback was not influenced by rate of photosynthesis or by amount of carbohydrate reserve. Reducing the light intensity 50 per cent each day had no effect on presence of foliar dieback.

Likewise, reduction in carbohydrate reserve due to high respiration rates at the 70 degrees temperature had no predictable effect on occurrence of leaf injury.

Foliar dieback was uncommon in four greenhouses inspected in Rockland County on November 22, 1944, in 24 inspected in the Rochester-Buffalo area on December 5–7, 1944, and in two large greenhouses inspected on December 24, 1944, in Woburn, Massachusetts. It was completely absent at all times during the 1944–45 season from the 1800 plants grown by an Ithaca florist. These plants were those remaining after the experimental planting was made for the present study.

An Illinois florist reported to the author in March, 1945, that in the new white-flowering variety Peace, plants from six of the eight single-plant selections were damaged by foliar dieback. Plants from two strains were severely damaged. The two strains unaffected by foliar dieback during the fall and winter suffered minor injury from it in late March. The florist reported that to all appearances the eight strains were practically identical in growth and development. In the two strains most seriously injured, 40 to 50 per cent of the plants were badly damaged. In the other four strains, serious injury occurred in only about 10 to 20 per cent of the plants.

These data on the variety Peace indicate that susceptibility varies within varieties, apparently as a multiple, heritable factor, leading to the hope that disease-resistance can be bred into varieties comparatively easily. Certainly, all future breeding work in snapdragons should consider resistance to foliar dieback a necessary characteristic.

The light intensity varied considerably from year to year for the fall and winter months in the 3 years under study, as is shown in Fig. 2. It is obvious, however, that the variation of the light intensity from the 3 year average was not correlated with the occurrence

of foliar dieback in 1942–43 and 1944–45, since the deviations from the average were in opposite directions for these 2 seasons.

Data for temperature differentials between the leaves and the air are not available. Presumably they often were 5 degrees C or more, since Curtis (3) found 5 degrees C the common temperature difference when the sun was visible. Possibly, foliar dieback starts during a stage of plant development when the cells surrounding the stomatal chamber are most susceptible to injury. Such an injury could be caused by a sudden increase in the water deficit following a rapid increase in rate of transpiration. Such a condition could occur when the leaf temperature increased rapidly because a cloud no longer prevented full infra red radiation from the sun. Repeated injury might lead to death of some cells, followed by a release of toxic disintegration products which caused the death of additional cells. According to microscopic study, the stomates are the region of initial injury in foliar dieback. Future work should study the correlation between leaf-air temperature differentials and occurrence of foliar dieback.

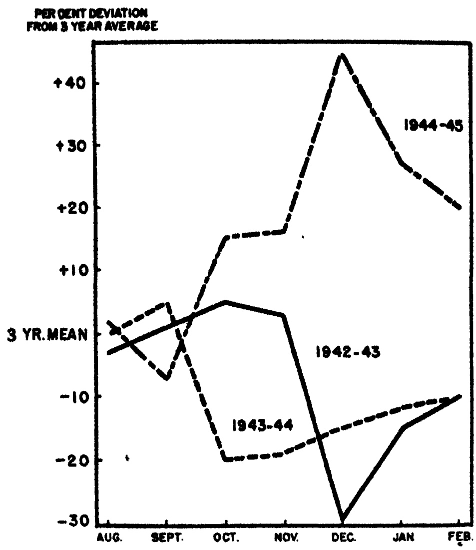

FIG. 2. Differences in total light energy received per month at Ithaca, N. Y. during 1942–45. (As measured by an automatic light recorded. (Post K. and Nixon, M. W. A graphic light meter. *Agr. Engineer.* 21(11): 429–30. 1940).

During September and October, 1942, also during October and November, 1944, there were many days when the light intensity was unusually high. A day completely free of clouds is rare at Ithaca, hence conditions probably were ideal on many days in these months for producing large leaf-air temperature differentials.

Curtis (2) showed that a leaf dieback in grasses was due to a reabsorption of guttated fluid through the stomates. Snapdragons are not known to have hydathodes, and no record of guttation was found in the literature. Careful observation of snapdragons was made during 1943–44. None of the common techniques for producing an external secretion from leaves were successful.

Solutions containing 0.2 per cent nitrate-N or 1.4 per cent urea were observed to cause severe leaf injury when sprayed on the leaves of plants of the variety Cheviot Maid Supreme. The injury occasionally bore a superficial resemblance to foliar dieback, but damage was

always confined to that which occurred within the first 3 days after treatment. Previous trials had shown that common nitrogen-carrying salts caused leaf injuries which resembled foliar dieback.

In an attempt to spread foliar dieback experimentally, concentrated aqueous suspensions made from damaged leaf material from plants of the varieties Koester's White and Cheviot Maid Supreme were prepared by grinding the material in a Waring Blendor. The suspension was applied immediately in six replications to leaves of both injured and uninjured plants of the same and the companion variety. Comparable leaves on the same plants were sprayed or dipped in distilled water as checks in each trial.

None of the numerous attempts to spread foliar dieback during November and December, 1944, were successful.

Flower Production and Quality

Flowers were cut twice weekly in the usual commercial manner. Flower production and stem lengths (in 3-inch grades) were recorded in 1944–45. Post (6) found flower quality in snapdragons correlated with stem length.

From Table III it is apparent that flower production and stem length for the plants receiving added nitrogen or potassium were at least as good as those produced by plants which received no added nitrogen or potassium. Some of the fertilized plots had soil nitrate concentrations which averaged during the season as much as 144 ppm nitrate (Spurway soil-test value), also 1 : 2 soil-water extracts which

TABLE III—Effect of Fertilizer on Flower Production and Stem Length

Treatment	Flowers/Plant						Average Stem Length (Inches)					
	WW*	KW**	CM†	A††	Md‡	Aver	WW*	KW**	CM†	A††	Md‡	Aver
Temperature 50 Degrees F												
No added fertilizer...	4.93	4.59	3.44	2.99	4.07	3.86	18.9	15.1	21.4	19.3	26.1	20.18
Ammonium sulfate..	5.18	4.64	2.89	3.23	3.84	3.95	19.8	14.1	19.8	19.1	24.3	19.41
Potassium nitrate...	4.60	4.57	3.27	3.33	4.23	4.00	18.7	13.0	19.9	18.4	22.3	18.47
Potassium chloride..	3.98	4.72	3.36	3.42	4.44	4.98	18.7	15.2	20.1	19.0	22.3	19.08
Temperature 70 Degrees F												
No added fertilizer...	4.30	5.20	4.90	4.10	4.00	4.50	16.3	12.1	17.3	16.9	17.7	16.04
Ammonium sulfate..	4.80	4.25	3.90	3.00	2.80	3.75	15.6	11.1	17.0	17.2	18.5	15.87
Potassium nitrate...	4.33	4.57	5.17	4.50	3.67	4.45	16.2	12.9	16.7	16.2	17.9	15.99
Potassium chloride..	4.23	5.30	5.53	4.53	3.37	4.59	15.4	13.1	16.4	16.9	17.4	15.85

*White Wonder.
**Koester's White.
†Cheviot Maid Supreme.
††Afterglow.
‡Maryland Pink.

averaged for the season a specific conductance of 253 x 10^{-5} mhos. These levels are considerably above those previously considered injurious to snapdragons.

Altering soil reaction (pH) likewise made no material difference in yield or quality (Table IV).

TABLE IV—EFFECT OF SOIL REACTION (pH) ON FLOWER PRODUCTION AND STEM LENGTH

pH	Flowers/Plant						Average Stem Length (Inches)					
	WW*	KW**	CM†	A††	Md‡	Aver.	WW*	KW**	CM†	A††	Md‡	Aver.
7.0–7.2	5.00	4.85	3.05	3.35	4.95	4.24	17.2	13.9	19.7	19.0	26.5	19.23
5.0–5.5	5.15	5.20	3.35	2.80	3.80	4.06	18.2	14.3	18.5	17.2	23.9	18.39

*White Wonder.
**Koester's White.
†Cheviot Maid Supreme.
††Afterglow.
‡Maryland Pink.

Plant growth was noticeably greater on muck, but there appeared to be no differences in growth on the soil mixtures of 1 : 1 : 1 or 1 : 1 : 0 soil-sand-peat versus the regular compost (Table V). Plants watered automatically were observed to be slightly taller than those surface-watered, but production and stem length was unaffected by high versus low soil moisture (Table VI).

TABLE V—EFFECT OF SOIL TYPE ON FLOWER PRODUCTION AND STEM LENGTH

Treatment	Flowers/Plant			Average Stem Length (Inches)		
	WW*	CM**	Aver.	WW*	CM**	Aver.
1:1:1 soil-sand-peat	4.45	3.58	4.01	18.8	21.5	20.18
1:1:0 soil-sand-peat	3.97	3.37	3.66	20.0	20.5	20.23
1:0:0 soil-sand-peat	4.48	3.85	4.17	17.8	18.9	18.35
82 per cent organic matter muck	4.03	4.13	4.08	19.2	20.6	19.93

*White Wonder.
**Cheviot Maid Supreme.

Flower production increased slightly under long days and decreased slightly under reduced light intensity (Table VII). Stem length was not materially altered by either treatment. The slight hastening of flowering due to the use of added light can be gained more economically by raising the air temperature.

TABLE VI—EFFECT OF SOIL MOISTURE ON FLOWER PRODUCTION AND STEM LENGTH

Flower/Plant						Average Stem Length (Inches)					
WW*	KW**	CM†	A††	Md‡	Aver	WW*	KW**	CM†	A††	Md‡	Aver
Soil at 3 Cm Hg. Tension											
4.03	3.93	2.70	2.87	3.23	3.35	21.5	16.1	22.1	21.0	25.7	21.27
Soil at 25 Cm Hg. Tension											
4.10	4.47	3.30	3.63	4.20	3.94	22.2	15.8	22.5	19.7	24.3	20.90

*White Wonder.
**Koester's White.
†Cheviot Maid Supreme.
††Afterglow.
‡Maryland Pink.

TABLE VII—EFFECT OF DAYLENGTH AND LIGHT INTENSITY ON FLOWER PRODUCTION AND STEM LENGTH

Treatment	Flowers/Plant						Average Stem Length (Inches)					
	WW*	KW**	CM†	A††	Md‡	Aver	WW*	KW**	CM†	A††	Md‡	Aver
50 Degrees F Night Temperature												
Normal day	4.48	4.13	3.85	3.45	4.38	4.06	17.8	13.8	18.9	18.5	22.7	18.33
4 hours light added	6.33	6.00	3.90	3.85	4.90	5.04	18.4	14.6	19.6	19.1	20.5	18.44
Reduced light intensity	3.98	3.95	2.48	2.58	3.65	3.33	17.9	16.4	20.9	18.3	25.4	19.11
60 Degrees F Night Temperature												
Normal day	10.83	6.75	6.23	5.58	9.33	7.74	14.8	12.7	17.3	17.9	17.1	15.95
4 hours light added	11.23	10.58	11.20	7.70	11.95	10.53	13.3	12.2	16.9	17.8	17.1	15.42
Reduced light intensity	7.70	6.63	5.35	4.70	7.13	6.30	15.4	13.6	17.9	16.4	18.8	16.43
70 Degrees F Night Temperature												
Normal day	5.03	5.28	5.33	4.35	4.45	4.89	16.2	12.6	17.2	17.6	17.5	16.20
4 hours added light	5.50	5.80	6.65	4.95	3.50	5.28	14.3	11.8	15.5	15.1	17.2	14.75
Reduced light intensity	3.20	3.95	3.78	3.50	2.48	3.38	16.3	12.7	17.1	16.8	18.5	16.25

*White Wonder.
**Koester's White.
†Cheviot Maid Supreme.
††Afterglow.
‡Maryland Pink.

Air temperature influenced production more than did any other factor studied. Flower production during the winter was nearly doubled by raising the temperature from 50 to 60 degrees F (Table VIII). However, total production for the year probably was unchanged. Stem length decreased about 15 per cent at 60 degrees F, but strength of stem seemed unaffected. Flower production at 70 degrees F was essentially the same at 50 degrees F, but stems were weak and the crop unsalable. The best temperature for growers to use appears to be 55 degrees F.

NITRATE-NITROGEN CONTENT OF SNAPDRAGON LEAVES

Leaf samples (5 grams fresh weight) of normal and diseased leaves (foliar dieback) were collected at intervals from the five varieties in the 1944–45 Ithaca planting. They were dried at 80 degrees C in a forced draft oven. Determination of the nitrate-N content was made on 271 samples by a Xylenol method (1) that gave an accuracy within the 10 per cent range (often within the 5 per cent range).

TABLE VIII—EFFECT OF TEMPERATURE ON FLOWER PRODUCTION AND STEM LENGTH

Treatment	Flowers/Plant						Average Stem Length (Inches)					
	WW*	KW**	CM†	A††	Md‡	Aver	WW*	KW**	CM†	A††	Md‡	Aver
50 degrees F	4.59	4.60	3.25	3.19	4.09	3.94	19.1	14.5	20.7	9.2	23.8	19.5
60 degrees F	9.80	7.79	7.21	5.91	9.37	8.06	14.3	12.7	17.3	17.5	17.4	15.8
70 degrees F	4.45	4.92	4.96	4.13	3.47	4.39	15.7	12.5	16.6	16.6	17.3	15.7

*White Wonder.
**Koester's White.
†Cheviot Maid Supreme.
††Afterglow.
‡Maryland Pink.

128 leaf samples (5 grams fresh weight) of 12 varieties were collected in 28 different greenhouses in New York, Massachusetts, and Ohio and brought to Ithaca sealed in glass jars. One drop of chloroform was used per sample as the preservative.

Care was always taken to collect only leaves of the same physiological age. The first "fully mature" leaf, counting from the apex of the branch, was used.

From Table IX it is apparent that the concentration of nitrate-N in the leaves did not correlate with incidence of foliar dieback or with observed differences in varietal susceptibility.

Effect of Root Injured on Occurrence of Foliar Dieback

Florists believe that snapdragons are particularly sensitive to root injury. Chlorosis is common where roots have been injured by symphillids or by excess soluble salts in the soil.

TABLE IX—Comparison of Average Nitrate-N Content in Normal Leaves of Uninjured Snapdragon Plants Versus Injured Leaves of Plants Where Foliar Dieback Developed—1944–45

Leaf Type	Number of Samples	Nitrate-N Content of Leaves	
		Mg/Gm Fresh Weight	Mg/Gm Dry Weight
	White Wonder		
Normal	28	0.598	1.545
Foliar dieback	7	0.608	1.467
	Koester's White		
Normal	67	0.474	1.290
Foliar dieback	82	0.551	1.177
	Cheviot Maid Supreme		
Normal	62	0.442	1.003
Foliar dieback	23	0.512	1.595
	Afterglow		
Normal	22	0.409	0.466
Foliar dieback	5	0.456	1.415
	Maryland Pink		
Normal	23	0.822	1.500
Foliar dieback	11	0.551	1.396
	Ethel		
Normal	6	0.378	0.990
Foliar dieback	1	0.768	1.262
	Ball Supreme		
Normal	6	0.543	1.302
Foliar dieback	1	0.744	1.063
	Christmas Cheer		
Normal	12	0.757	2.036
	Mary Ellen		
Normal	11	0.757	2.201
	Peace		
Normal	4	0.603	1.877
	Carol Jean		
Normal	4	0.862	2.397

To observe the effect of mechanical injury to the root system, 18 potted plants (Cheviot Maid Supreme and Afterglow) were shifted from 3-inch pots to 4-inch pots on October 29, 1943, according to the following plan: (a) With as little root injury as possible, (b) all soil washed from the roots by the use of a stream of water; no attempt made to minimize root injury, and (c) all roots visible on the surfaces of the soil ball ripped off.

All plants in treatments b and c wilted slightly each day during the first week after the root injury occurred. There was no other effect visible at any later date. None of the plants in the experiment were affected by foliar dieback.

To observe the effect of exposure of plants to the sunlight after the soil was allowed to cool considerably during the night, eight plants of the variety Koester's White were grown at 65 degrees F in 6-inch pots of the Elba muck and stored from 5 p. m. to 8 a. m. nightly in a refrigerator at a 40 degrees F temperature from November 15, 1944 to January 27, 1945. Wilting was never observed, and none of the plants was affected by foliar dieback. It is possible that the soil may have warmed sufficiently by the time the direct rays of the sun reached the plants to provide water at the necessary rate. The experiment should be repeated to expose the plants to the sun directly, say at 11 a. m. instead of at 8 a. m.

Altering Soil Aeration

Tests to determine the effect of sudden, drastic changes in soil aeration were conducted. Four plants each of the varieties Cheviot Maid Supreme and Koester's White were grown in 4-inch pots in a 9: 1 sand-soil mixture until the flower buds started to open. They were then stored over-night in water deep enough to cover the entire pot. Similar plants had the entire pot dipped into liquid paraffine to coat the pot walls and the surface of the soil except for the ⅛-inch area immediately surrounding the stem of the plant. Other plants were sealed into water-tight metal cans, leaving only a small tube for gaseous exchange and for watering. All plants were observed daily until they became so deficient in nutrients that they had to be discarded. Foliar dieback never occurred.

Alternate Drying-Wetting of the Soil

After the main 1944–45 experiment with potted plants in muck was completed, the muck was allowed to dry until it felt powdery to the touch. The plants suffered incipient wilting. The pots then were watered heavily every 2 hours until the muck seemed saturated with water. No more water was used until the plants again suffered incipient wilting each day. Four such drying-wetting cycles were completed by April 1. During this time the plants were inspected regularly for appearance of foliar dieback. None was ever found.

Summary

Foliar dieback of greenhouse snapdragons is widespread only in occasional years. When serious it may completely destroy the crop.

Florists usually first become aware of the presence of foliar dieback when flowering stems suddenly fall over just as the flower buds swell in opening. Injury may spread rapidly through the crop.

Characteristics of the damage are those of a physiological disease. No pathogen ever has been correlated with initiation of the trouble. Foliar dieback has never been produced experimentally. Attempts to spread it from affected plants have failed.

None of the factors studied was in itself responsible for initiation of the condition. None by itself influenced the severity of damage. These factors were nitrogen and potassium nutrition, soil reaction (pH), soil type, soil moisture, daylength, light intensity, and air temperature.

Nitrate-N content of the leaves did not correlate with incidence of foliar dieback, or with the observed varietal susceptibility differences. The former invalidates Wilson's suggestion that severity of foliar dieback correlates with the nitrate-N content of the leaves.

Spectrographic analysis indicated that injured leaves contained two or more times the amount of lead, barium, boron, aluminum, strontium, and iron present in uninjured leaves.

Varietal susceptibility to foliar dieback was very marked. Koester's White should not be grown in New York. Cheviot Maid Supreme, and selections from it, should be grown only in limited numbers. Susceptibility appears to be a heritable character within a variety. Future breeding should consider resistance to foliar dieback a characteristic to be bred into new varieties.

Flower production and quality were not affected appreciably by relatively large variations in nitrogen and potassium fertilization, soil reaction (pH), soil type, soil moisture, daylength, or light intensity. Flower production during the winter months was nearly doubled by raising the air temperature from 50 to 60 degrees F, but stem length of the flowers was reduced 15 per cent.

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New Hardy Lily Hybrids

By C. F. PATTERSON, *University of Saskatchewan, Saskatoon, Sask.*

WITH a view to obtaining a departure from the orange colored flower found in most of the lilies possessing extreme hardiness, the author began, a few years ago, a project in the breeding of hardy lilies. The chief colors sought in these lilies, when the project was undertaken, were white and pink in a variety of intensities.

Two of the lilies chosen to provide the bases for the colors desired were the Regal (Lilium regale) to supply white and the Nodding (Lilium cernuum) to supply pink. Though grown successfully out of doors in the prairie provinces in a few cases, the Regal lily was found to lack the hardiness required by perennial plants for the Far North. The Nodding lily, the nearest approach to a hardy pink lily, proved not to be at home under the conditions prevailing on the northern prairies and was found to lack dependability. Further, the flower of this lily is not a true pink but is a pink carrying considerable blue and is lacking in size.

FIG. 1.

The first pink hybrid obtained was from the combination L. willmottiae x L. cernuum. The plant is a stronger grower than that of L. cernuum and produces larger flowers and a greater number of flowers per plant. Numbers up to 30 have been produced on a stem of a plant growing under ordinary conditions. The flowers are of the reflexed type and in form are not unlike those of L. willmottiae. The blueness present in flowers of L. cernuum is absent in the flowers of this hybrid and the color might be described as medium pink. A small group of plants of this hybrid is shown in Fig. 1.

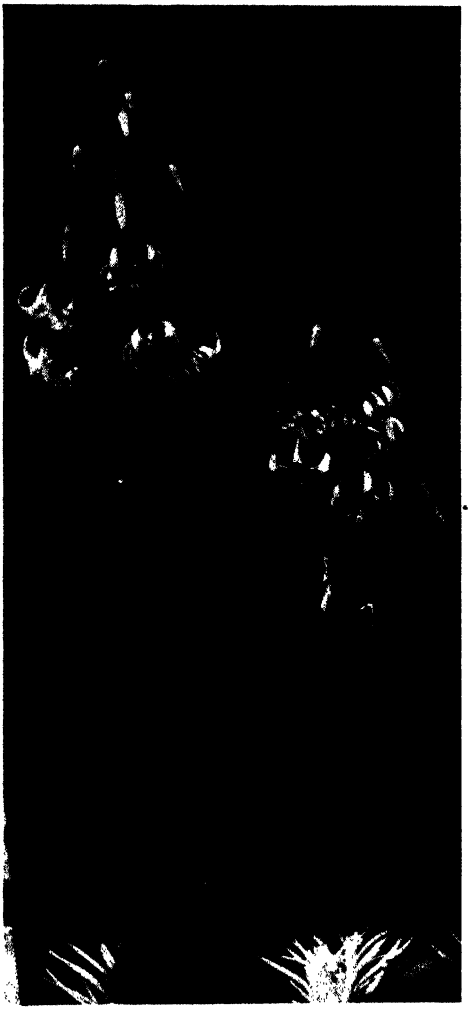

FIG. 2.

The pink flowered hybrid shown in Fig. 1 proved to be almost sterile as a female parent but produces pollen that is fertile to a high degree. This lily has been used extensively as a male parent and its use has resulted in a large number of seedlings with flowers ranging from pure white to deep pink. A variety of material has been used as female parents comprising a few species, a few named varieties and our own hybrids in considerable numbers.

The lilies shown in Figs. 2 and 3 are hybrids involving four species. The female parent is a trihybrid involving L. willmottiae, L. elegans and L. tigrinum. The male parent is the hybrid shown in Fig. 1. The color of the lily in Fig. 2 is a beautiful deep rose pink and the tallest plant reached a height, in 1945, of nearly 4 feet. The flower of the lily in Plate 3 is pale cream with a slight suggestion of pinkishness in places on the divisions of the perianth of newly opened flowers. This tinge of pinkishness disappears in a short time in the presence of sunlight. This plant reached a height of 3½ feet in 1945.

The height to which the plants of these hybrids will grow and the size that the flowers will attain are undetermined in nearly all the selections made. Most of these selections were made during the years 1944 and 1945, from small plants, and full size bulbs have not been produced as yet. The three shown in Figs. 1, 2 and 3 were selected earlier and the plants and flowers of these may be approaching full size.

The progress made in this project to date is very encouraging. Promise that this group of hybrids will make a distinct and a sub-

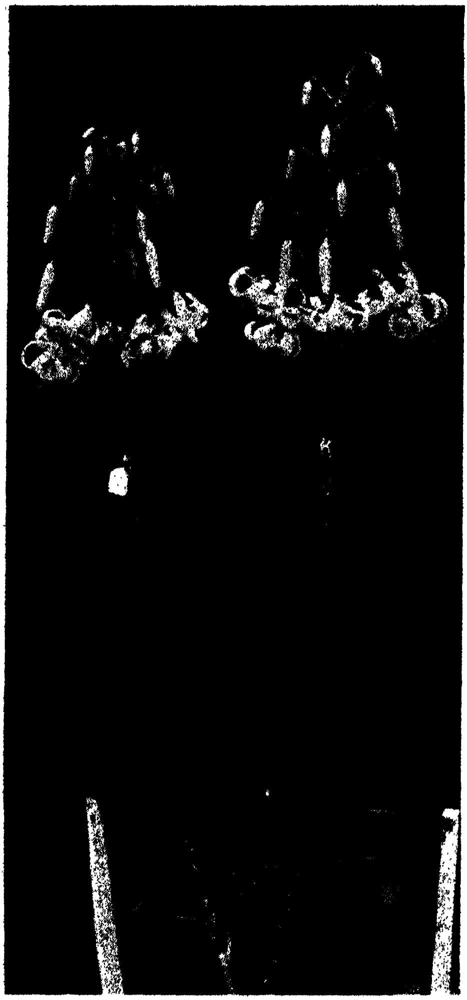

Fig. 3.

stantial contribution to the group of very hardy lilies now in commerce is in evidence. What the measure of this contribution will be, time only shall reveal.

Reduction of Blindness in Hydrangeas

By STEPHEN RAY, *Ohio State University, Columbus, O.*

FAILURE to initiate flower bud in hydrangeas which are used for forcing in the greenhouse constitutes a serious loss to growers. This trouble has been attributed to various causes such as the use of weak cuttings for propagation, inadequate fertilizers, late pinching, and unfavorable weather. Although these are undoubtedly contributing causes, the chief reason is the inadequate accumulation of carbohydrates for the initiation of flower buds.

Previous work done at the Ohio Agricultural Experiment Station by Laurie and his assistants has shown that if hydrangeas are allowed to develop large foliage during the summer out of doors, adequate food will be made early in the summer to develop flowering buds and eliminate the usual high percentage of vegetative stems (blind). The procedure proposed by the workers at Ohio was to set potted plants of hydrangeas, propagated in March, under lath in June, and pinch them to two or three nodes early in July. Grown in this manner, with maintenance of adequate nutrient levels (N–25, P–25, K–25, Ca–150) and high humidity, the foliage becomes heavy and large and the stems especially strong. The removal of the partial shade provided by the lath, early in August, exposes large leaf surface to full sunlight and the ensuing photosynthetic activity causes high accumulations of carbohydrates and rapid setting of flower buds.

In tests conducted in 1944–45, all plants were placed in 3-inch pots from the cutting bench except one lot which was potted into 6-inch pots directly from the propagation bench. The rest were shifted from 3-inch pots to 5-inch pots the middle of May and taken outside, some under lath and some in full sun (field grown) the first week of June. The plants were pinched June 30. On August 1 all shade was removed from the plants under lath. All plants were shifted to 6-inch pots in early September and were placed in frames for frost protection. On November 1 the plants were placed in a dark storage at 40 degrees F and left there until the end of December when they were brought into the greenhouse for forcing in a starting temperature of 55 degrees F.

In addition to taking several types of cuttings (thin wood, heavy wood, and leafbud) there were two dates of propagation, February 16 and March 13.

An examination of Table I shows that the difference between thin wood, heavy wood, and leafbud cuttings used in propagation of the two varieties, Europa and Kunert, is not significant. Contrary to popular belief, there was no appreciable difference in the size of the plants or flower heads when propagated from the two types of wood and in the two ways. In many cases the leafbud cuttings produced plants which were larger and had larger heads than the plants produced from stem cuttings. Plants shifted directly into 6-inch pots from the propagation bench were taller and had larger flower heads than any other treatment. Although the direct shift requires the use of greater space in the greenhouse, this is only for a short period and there is a considerable reduction in the labor required to produce the plant when handled

TABLE I—THE EFFECT OF SEVERAL TREATMENTS ON THE FLOWERING OF HYDRANGEA

Growing Location	Type of Cutting	Time of Taking	Amount of Peat in Soil	Europa		Kunert	
				Average Number Shoots Per Plant	Per Cent of Flowering Shoots	Average Number Shoots Per Plant	Per Cent of Flowering Shoots
Lath	Thin	2/16	1/3	4.8	99	5.2	96
Lath	Leafbud	2/16	1/3	4.1	98	4.5	99
Lath	Heavy	2/16	1/3	4.1	100	3.8	99
Lath	Thin	3/13	1/3	4.3	100	4.0	93
Lath	Leafbud	3/13	1/3	3.7	100	4.4	88
Lath	Heavy	3/13	1/3	4.5	100	5.2	97
Lath*	Heavy	3/13	1/3	4.2	100	4.8	96
Lath	Heavy	3/13	None	4.0	99	5.0	85
Field	Heavy	3/13	1/3	3.6	90	5.9	87
Field	Heavy	3/13	None	3.0	95	5.6	78

*Direct to 6-inch pots from the propagation bench.

in this way. Both the February and March propagations were approximately the same size at maturity.

Plants grown in the field were shorter than those under lath and, as shown in the table, produced fewer flowers due to a higher percentage of blindness. This is undoubtedly due to the vegetative growth made by these plants late in the summer rather than during the early summer. The removal of the partial shade August 1 from the plants grown under lath resulted in a greater storage of food late in the summer and consequent formation of flower buds.

The omission of peat moss from the potting soil resulted in smaller, thinner plants. The presence of peat moss in the potting soil was found to be beneficial. An inspection of the root systems of plants growing in the soil in which peat had been added showed that wherever lumps of peat were present they were filled with active roots.

From completely blind plants of Europa, 50 stem cuttings and 50 leafbud cuttings were propagated and grown under lath as previously described. Both the leafbud and stem cuttings produced an average of 4.5 stems per plant with 98 per cent flowering shoots. This disproves the belief that cuttings from completely blind plants will not flower.

The conclusions from this series of tests are: The type of wood for propagation (thin, heavy, or leafbud) makes little difference in the quality of the mature plant. In field *vs.* lath house culture, lath is superior in quality of plant produced and reduced blindness. Shifting cuttings direct to 6-inch pots produces large plants with large flowers at a reduction in labor but with an increase of greenhouse space required prior to moving to the field. The addition of ⅓ peat moss to the potting soil is beneficial. Cuttings of blind wood will produce flowering plants, even if the stock plants are completely blind.

Sodium Selenate for Red Spider Control in Massachusetts[1]

By Harold E. White and Warren D. Whitcomb,[2]
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Historical

About 10 years ago, one of the popular and highly advertised spray materials for combating the red spider mite on greenhouse crops was potassium ammonium seleno-sulfide $(KNH_4S)_5Se$, known commercially as Selocide. In 1937 and 1944, experiments by Neiswander and Morris in Ohio (2) showed a significant degree of immunity to the red spider mite in certain greenhouse plants by adding various amounts of sodium selenate to the nutrient solution in which the plants were growing. They found that a selenium concentraton of 45 to 100 parts per million in the leaves, depending on the species of plants, was necessary to give protection against red spider and that a solution of 1 to 2 ppm. was generally a satisfactory concentration to add to the nutrients. When carnations were grown in soil as much as 10 ppm. of selenium were used. In these experiments it became apparent that selenium was taken much less easily by roses, which are typical woody plants, than by rapidly growing annuals such as tomatoes.

Interest in this treatment apparently died out for a few years until it was revived in 1943 and 1944 by Blauvelt (1) in New York who secured excellent protection against red spider on carnations by treating the soil with sodium selenate, and sodium selenate combined with superphosphate.

Materials

Sodium selenate (Na_2SeO_4) is a white crystal which is usually colored blue as a warning that it is poisonous to humans. The crystals are soluble in water at the rate of 111 grams in 100 ml at 35 degrees C.

P 40 is a commercial preparation containing 2 per cent sodium selenate combined with superphosphate, and is usually prepared as small pellets. Although the sodium selenate is equally soluble in this form, it becomes available more slowly when combined with superphosphate.

Methods of Application

Where large quantities are used, a power spray machine or a Hozon proportioner is recommended for applying sodium selenate solution. In the experiments at Waltham, the crystals were dissolved and applied with a quart of water for each 8-inch clay pot, or to a bench at the rate of 25 gallons of diluted solution to 100 square feet.

The P 40 pellets were spread uniformly on the soil at the desired rate and the soil was watered as needed. Three pounds of P 40 pellets to 100 square feet of soil are equivalent to a dosage of ¼ gram of sodium selenate to a square foot.

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[1]Contribution No. 585, Massachusetts Agricultural Experiment Station.
[2]The authors gratefully acknowledge the assistance of William J. Garland, Technical Assistant in Entomology.

Tests on Potted Plants

In the first tests at Waltham, 15-month-old carnations in 8-inch clay pots were treated with P 40 on March 12. The plants were artificially infested with a large number of spiders on March 30 at which time it was believed that the plants had taken up considerable selenium. The dosages varied from ½ ounce to 2 ounces of P 40, equivalent to ¼ gram to 1 gram of sodium selenate, but since the surface area of an 8-inch pot is only 50 square inches, the dosages were actually about three times as great as recommended by Blauvelt.

Counts made at approximately monthly intervals after the plants were infested showed a very noticeable reduction in the spider population for about 4 months; but there were indications in August, 5 months after treatment, that the effect of the treatment was wearing off and the number of spiders was increasing.

As shown in Table I, the 1½-ounce and 2-ounce dosage of P 40 gave almost complete protection against red spider mite.

TABLE I—Effect of P 40 on Red Spider Mite on Potted Carnations*

Amount P 40 per 8-inch Pot**	Average Live Mites per Leaf			
	May 3	Jun 8	Jul 10	Aug 13
None	20.6	6.1	1.7	7.9
½ ounce	6.7	7.8	1.3	10.3
1 ounce	2.2	4.2	0.0	0.0
1½ ounces	0.2	1.6	1.1	6.1
2 ounces	0.1	0.2	0.0	0.7

*Plants about 15 months old when treated. Treated March 12, 1945. Infested March 30, 1945.
**8-inch clay pot contains 50.27 square inches soil surface.

The most striking observations in this test occurred when shoots from treated plants remained free from spiders when they were accidentally bent over and grew among the heavily infested shoots of the untreated plants.

In a second test on potted carnations, infested plants in 8-inch clay pots were examined at 10-day intervals after treatment as shown in Table II. During the first 10-day period no effect from the treatment was evident. During the second 10-day period the spider population on the treated plants was reduced to a population about equal to the original infestation, while that on the untreated plants had multiplied three times. At the end of 30 days, a definite reduction was apparent and the greater dosage had caused practical immunity.

Both P 40 and sodium selenate solution were used in these tests. During the first 10-day period there was no apparent difference between these materials but in the 20-day period it became evident that the plants were taking up the sodium selenate solution more quickly.

As in the experiment summarized in Table I, the dosage in this test was greater than the general recommendations, and injury to potted carnations occurred where sodium selenate solution was used. This injury began to appear in the 10 to 20 day period after treatment and in 30 days it had become severe from all dosages above ¼ gram. Many of the treated plants died.

TABLE II—Time Required for P 40 and Sodium Selenate to Reduce Population of Red Spider Mite on Potted Carnations*

Amount Per 8-inch Pot	Average Live Mites Per Leaf				Per Cent Increase/ Decrease After 30 Days
	Before Treatment	After 10 Days	After 20 Days	After 30 Days	
		P-40			
None	3.2	5.6	10.0	10.6	+231.25
½ ounce	7.2	6.7	5.0	3.3	−54.16
1 ounce	4.5	6.6	5.5	4.4	−2.22
1½ ounce	5.1	6.7	5.9	1.5	−70.59
2 ounces	3.8	7.2	3.3	0.1	−97.36
		Sodium Selenate Crystals			
None	6.8	7.4	10.6	16.4	+141.17
¼ gram	4.7	5.3	3.0	0.8	−82.98
½ gram	4.2	5.8	2.5	2.2**	−47.62
¾ gram	4.5	6.0	2.2**	1.2**	−73.33
1 gram	5.5	6.5	1.6**	1.0**	−81.82

*Treated September 18, 1945.
**Plants injured by treatment; count incomplete.

Applications to benches of carnations at the Waltham Field Station were made on July 21, using P 40 at the rate of 1 to 2 ounces per square foot. Counts on September 5, 45 days after treatment, showed an average of 4.2 spiders per leaf, while on benches where the selenium was not applied a heavy infestation averaging 19.3 spiders per leaf had developed. A second application of P 40 was made to these benches on October 15, and counts on December 14 failed to show a live spider on these plants. However, the untreated benches had become so heavily infested that it was necessary to spray them with insecticides and significant counts could no longer be made. No injury to any of these plants was observed.

In another experiment rooted carnation cuttings in plant bands were treated with ½ to 1 ounce of P 40 per square foot on March 16 while they were in the flats. The flats were placed in cold frames in early April and received several drenching rains as well as the necessary watering. About June 20 they were placed in the greenhouse benches without further treatment. Counts on September 5 showed an average of only 1 spider per leaf, while other plants which had not received treatment in the flats were very heavily infested by an average of 32.3 spiders per leaf. No injury developed on the treated plants.

A second application of P 40 averaging 1 to 2 ounces per square foot was made on October 15. Counts on December 14 showed 14.14 spiders per leaf on these plants, indicating that the effect of the flat treatment had been lost and that the slowly soluble P 40 had not yet checked the newly developed spider infestation.

In 1945 several commercial carnation growers in eastern Massachusetts treated their plants with generally favorable results. Some growers were dissatisfied because the treatments did not become effective quickly enough on plants already infested. In a few cases a stunting of the plants, presumably due to the treatment, was reported.

One of the most comprehensive tests by growers was made at the R. M. Davenport Greenhouses in Lexington, Massachusetts. Benches

of Puritan Carnations, benched on June 9, were treated July 1 with sodium selenate at the rate of ¼ gram per square foot applied with a power spray machine using 25 gallons of solution per 100 square feet of bench. Counts on December 18 showed an average of 0.5 spider per leaf, while adjacent untreated benches were infested by 3.4 spiders per leaf. On other benches of Cardinal carnations, applications of sodium selenate solution at the rate of ¼ gram of selenium per square foot were made on May 30 and again on June 28. On December 19 no spiders were found on these plants, while untreated Cardinal carnations growing in the same greenhouse averaged 1.7 spiders per leaf.

Precautions

It is evident that injury to carnations and other plants may occur from excessive dosages of sodium selenate, particularly where solutions of the pure chemical are applied. P 40 is much less likely to cause injury because it is slowly soluble.

Vegetables or other crops such as hay or green fodder that are fed to animals should not be grown on soil which has been treated with selenium. Even after the treated soil has been carried to the field, this danger may persist for several months.

Conclusions

Sodium selenate has been definitely shown to be toxic to the red spider mite. It becomes effective more quickly in fast-growing herbaceous plants than in slow-growing woody plants. The most satisfactory dosage for carnations appears to be ¼ to ½ gram sodium selenate per square foot applied as pure sodium selenate crystals in solution, or as the equivalent amount of P 40. Treatments become effective in about 30 days and should continue to give protection for 3 months or longer. Demonstrations in commercial ranges have shown this treatment to be a practical method for controlling the red spider mite on carnations.

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Effect of Height of Topping on Antirrhinum Majus

By J. R. KAMP and S. W. HALL, *University of Illinois, Urbana, Ill.*

IN ORDER to determine the effect of two different heights of topping on the number of shoots originally produced, on the total production of flower spikes and their length, and on the time of flowering, 514 snapdragon plants, representing six well known greenhouse varieties, were used.

The plants were placed in the bench, 9 by 8 inches apart, on August 9, 1945. On August 22, half of the plants were topped just above the third node, and half just above the fifth node. In all other respects, they received similar treatment.

Counts made on September 22 showed an average of 3.72 shoots on the plants topped at the third node, and 4.35 shoots on plants topped at the fifth node. This difference was not consistent, however, in the different varieties (Table I). The first blooms were cut on September 24 and weekly records were kept of the cut from that date until January 12, 1946. At the end of this 16-week period, the main crop had been cut off and the experiment was discontinued.

TABLE I—EFFECT OF TOPPING ON YIELD, SPIKE LENGTH, AND TIME OF BLOOM OF ANTIRRHINUM MAJUS VARIETIES

Variety	Node to Which Topped	Average Shoots on Sept 22, 1945	Average Spike Length (Inches)	Average Spikes Per Plant	Increase in Numbers of Spikes (Per Cent)
Feist's White	3	2.83	19.52	5.33	
	5	4.80	17.79	7.90	48.2
Junglewood White	3	3.98	40.82	2.62	
	5	3.97	35.58	3.27	24.9
Better Times	3	3.33	17.65	8.00	
	5	5.92	15.21	11.00	37.5
Yellow Wonder Improved	3	3.64	17.51	5.14	
	5	3.31	16.29	6.03	17.3
Carol Jean	3	3.29	28.19	3.60	
	5	4.31	25.14	5.06	40.5
Glorious	3	5.25	16.40	5.42	
	5	3.79	13.20	5.60	3.3
All varieties	3	3.72	23.36	5.02	
	5	4.35	20.54	6.48	29.1

In all six varieties, the lower topping produced longer spikes (Table I). Spikes from the plants topped low and high averaged 23.36 and 20.54 inches respectively. Only those spikes which were sufficiently well flowered to be marketable were considered. Although the length of the inflorescence proper was not measured and differed widely between varieties, in any one variety there was no noticeable difference as a result of the two treatments.

The plants topped at the third node produced an average of 5.02 spikes per plant, while those topped at the fifth node produced 6.48 spikes per plant. The increase in number of spikes with the higher

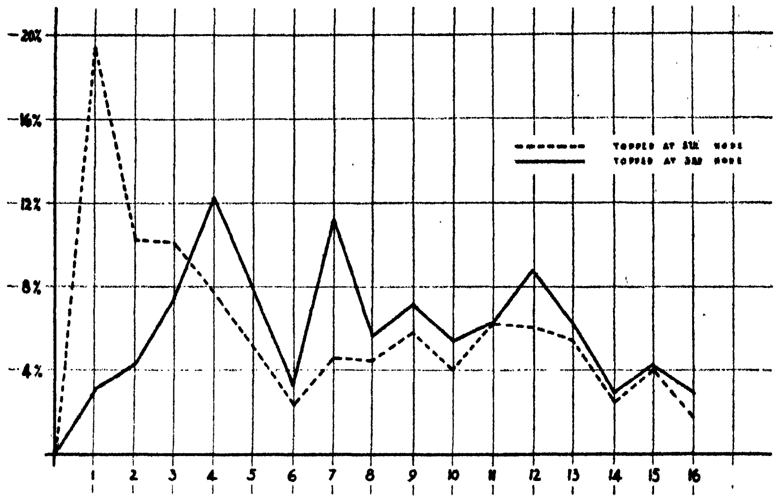

FIG. 1. Percentage of total flower cut harvested each week of season.

topping varied from 3.3 per cent to 48.2 per cent according to variety, but the trend was consistent in all cases. On the average, the increase was 29 per cent.

In all varieties, plants topped at the fifth node came into production earlier than those topped lower, and held this production lead for several weeks. In Fig. 1, all varieties have been grouped together and the production of spikes per week has been expressed as percentage of the total production over the sixteen week period.

In the varieties tested, all except Glorious retained sufficiently long stems under both treatments to be commercially salable. Topping at the fifth node can, therefore, be recommended as giving both a greater number of spikes and also an earlier crop. In varieties, such as Glorious, which have a tendency toward the production of short stems, topping at the third node might be preferable.

Experiments with Carnations

By F. F. WEINARD and J. R. KAMP, *University of Illinois, Urbana, Ill.*

CARNATIONS used in the experiments described below were propagated January 12, 1944. The rooted cuttings were planted in wood bands, and on June 14 they were planted 8 by 8 inches in the greenhouse benches. Records were kept of the flowers cut from November 11, 1944 through May 17, 1945. On January 12, 1945, about two cuttings per plant were taken, equal numbers from each plot. These shoots were counted as flowers.

EXPERIMENT 1. *Yields in relation to number of shoots at planting time:* — Seventy-two plants of Olivette with three shoots each, and an equal number with five shoots each, were distributed in six different plots. The yields for the season are shown in Table I.

TABLE I — FLOWER PRODUCTION BY SELECTED OLIVETTE CARNATIONS

Plot	Average Number of Flowers Per Plant		Average Number of Flowers Per Square Foot	
	Three-shoot Plants	Five-shoot Plants	Three-shoot Plants	Five-shoot Plants
1	9.2	9.8	20.9	22.3
2	10.7	12.2	24.2	27.5
3	7.9	10.0	17.9	22.6
4	9.1	10.6	20.6	24.0
5	8.4	11.2	19.1	25.3
6	7.9	11.8	17.9	26.8

It will be noted that differences were consistent in all plots. Three-shoot plants averaged 20.0 flowers, and five-shoot plants averaged 24.6 flowers, per square foot of bench space. Stems averaged 20.4 and 21.7 inches, and flower diameters 3.0 and 2.9 inches, respectively.

These preliminary results indicated that carnation plants in their first season in the bench did not outgrow the start given by the greater numbers of shoots at time of benching. The experiment is being repeated on a larger scale.

EXPERIMENT 2. *Productiveness of Carnations on New and Old Soils:*—Soil used previously for different lengths of time for growing carnations was sterilized with steam before the new planting was made. Subsequent flower production is shown in Table II.

It was apparent that there was little variation in the crops cut from plants on recently steamed 2 and 4-year-old soil, as compared with new soil. The 27-year-old soil was a very light compost, located in a separate house of mixed crops, where a severe infestation of red spider injured the carnations.

EXPERIMENT 3. *Results with Carnations Propagated from "Mosaic-Free" Stock Plants:* — Cuttings were taken from King Cardinal plants, presumably free from mosaic, grown by Dr. D. B. Creager. Plants for comparison were propagated from stock growing in a bench where mosaic was prevalent. While these are referred to as "unselected", the cuttings were taken from the vigorous plants only, and the

TABLE II — FLOWERING OF CARNATIONS ON NEW AND USED SOIL

Age of Soil	Number of Plants	Flowers Per Square Foot	Average Stem Length (Inches)	Average Flower Diameter (Inches)
		Charm		
New.......	54	10.9	26.0	3.2
4-year......	372	10.4	26.0	3.3
27-year.....	48	10.4	24.8	3.3
		King Cardinal		
New.......	215	15.9	23.4	3.4
2-year......	216	15.9	24.1	3.5
27-year.....	54	10.2	24.0	3.3
		Olivette		
New.......	54	23.0	19.5	2.8
4-year......	377	22.7	19.8	2.9
27-year.....	54	14.2	21.1	2.7

strongest of the young plants were selected, following ordinary commercial practice. Data from the two lots of plants grown on adjacent plots are given in Table III.

TABLE III — YIELDS FROM "MOSAIC-FREE" AND UNSELECTED KING CARDINAL CARNATIONS

Stock	Number of Plants	Flowers Per Square Foot	Average Stem Length (Inches)	Average Flower Diameter (Inches)	Flecked (Per Cent)
"Mosaic-free"	150	18.2	23.7	3.4	10
Unselected...	215	15.1	23.8	3.4	20

The yield was lower and the proportion of poor quality flowers was higher with unselected plants. The percentages of flecked blooms given in the table refer to the proportions of badly white-streaked flowers of inferior quality cut during the late winter months. As a matter of fact, most of the flowers cut from this variety appeared to be flecked in some degree.

Creager (1, 2) has pointed out that carnation mosaic may be responsible for reducing the number of flowers cut as well as the quality of the crop. The fact that flecked blooms were cut from the "mosaic-free" strain is probably explained by Jones' statement (3) that mosaic is spread readily by mechanical contact in cultural practices.

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Saintpaulia Leaf Spot and Temperature Differential

By FRANCES HELEN ELLIOTT, *Cornell University, Ithaca, N. Y.*

SAINTPAULIA leaf spot appears as small chlorotic areas in the leaf. The injury may occur as a white spot, roughly circular in outline, or as a ring spot, with normal green tissue inside the white ring. It is not known to be associated with any pathogen. Poesch (4) produced this spot by allowing cold water to drop on the leaves. He suggested that the temperature differential between the drop of water and the leaf might be the cause of the injury.

Kramer (3) investigating the effects of drops of water on leaves, found that in all of the plants he investigated, wetting a leaf caused it to drop to the temperature of the air. With Saintpaulia leaves in the sun, he found that at air temperatures of about 75 degrees F, the leaf temperatures were 97 to 108 degrees F. On wetting, leaf temperatures dropped to about 79 degrees. He did not report the temperature of the water used. He also found that wet leaves were less likely to be injured by strong light than dry ones, and attributed this to the cooling effect of evaporation. He thought that drops of water on leaves exposed to the sun probably never caused injury.

Curtis (1) and Curtis and Clark (2) showed that with fruits a differential of 5 to 20 degrees caused distillation of water from the high temperature area to the low temperature area. Injury occurred due to dessication of the high temperature area and bursting of the low temperature, water-receiving area.

It seems likely then, that the injury in Saintpaulia leaf spot may be connected with localized temperature gradients. To test this hypothesis, the following experiments were conducted.

Effect of Sunlight on Leaf Temperature:—To determine the effect of sunlight on leaf temperature, thermocouples were placed in the leaf of a Saintpaulia growing in the greenhouse. The light intensity reaching the leaves, as measured by a Weston photometer, was 4000 foot candles for leaves in the sun, and 500 foot candles for leaves in the shade.

TABLE I—COMPARISON OF AIR* AND LEAF TEMPERATURE

Position of Thermocouple	Temperatures Recorded at Minute Intervals (Degrees F)				Average
In the air, in the sun..	81	81	82	79	80.75
In the leaf, in the sun..	95	96	98	97	96.50
In the leaf, in the shade	80	79	79	79	79.25
In the air, in the shade.	78	77	77	77	77.25

*Air temperatures were recorded at the level of the leaf surfaces. Repetitions of the experiment with the thermocouples interchanged gave similar results. Under these conditions, the intensity of light to which the leaf was exposed determined the temperature differential between the leaf and the surrounding air. At 500 foot candles, the leaves were 2 degrees above air temperature. At 4000 foot candles, the leaves were 16 degrees above air temperature.

Temperature Decrease:—To determine the temperature change brought about by cold water on the leaf, one thermocouple was placed near the petiole, and one near the tip of the leaf in the sun. The temperatures of the two thermocouples were followed for several minutes and found to be the same. Ice water was dropped on the tip of the leaf above the thermocouple and temperatures taken at intervals of 10 seconds. The temperature of the leaf dropped 35 degrees in 30 seconds. The immediate result was a darkened area of tissue in the position covered by the cold water. Within a week the dark area became a white leaf spot.

TABLE II—EFFECT OF ICE WATER ON LEAF TEMPERATURES

Reading Intervals (Seconds)	Temperature of Tissue Under Ice Water (Degrees F)	Temperature of Tissue Not Under Ice Water (Degrees F)
10	80	95
20	75	—
30	60	—
40	68	—
50	69	—
60	71	93

To determine the effect of temperature change on the leaf not associated with the application of cold water, a knife was plunged in snow for several minutes, and quickly dried; then the back of the knife was gently touched to the leaf. A typical white area, the shape of the area touched by the knife, appeared within a week.

Leaf spot occurs naturally as either ring or solid spot. The injury caused by the ice water was of the solid spot type. Where ice water dripped to a lower leaf, a line along each side of the rivulet of ice water showed typical white tissue. Perhaps a temperature differential of a lesser degree than that obtained with ice water on a leaf in the sun causes injury of the ring spot type.

Temperature Increase:—If temperature differential, not low temperature, causes this injury, a temperature increase should show similar results. The experiment recorded in Table II was repeated, except that water at 150 degrees F was used in place of ice water. The resulting temperature changes are shown in Table III.

The temperature of the leaf increased 30 degrees in 40 seconds. This treatment killed all tissue under the drop, but left a white ring around the dead area very similar to leaf spot.

TABLE III—EFFECTS OF HOT WATER ON LEAF TEMPERATURES

Reading Intervals (Seconds)	Temperature of Tissue Under Hot Water Drip (Degrees F)	Temperature of Tissue Not Under Hot Water (Degrees F)
10	108	95
20	112	—
30	115	—
40	122*	—
50	108	—
60	102	92

*Hot water was continuously dripped on for the first 40 seconds.

Anatomy of Leaf Spot:—Leaf sections of natural injury were prepared by the paraffin method and stained with safranin and aniline blue. The leaf spot areas were identified by the use of 1 per cent acid fuchsin in the killing agent (formalin-aceto-alcohol) in the preparation of some of the slides. The stain left all normal tissue a light brown, but left spotted areas translucent. The illustration is typical and shows the collapsed cell walls of the palisade layer in the injured area, and the normal appearance of the remainder of the leaf section.

Discussion

Localized tissue temperature differentials of 35 degrees F result in Saintpaulia leaf spot. Differentials of a lesser degree, such as would be obtained by a reduction in light intensity or the use of warmer water were not studied. Observations, however, indicate that the ring spot type of injury may be caused by tissue temperature change of a lesser degree than is necessary to cause solid spot.

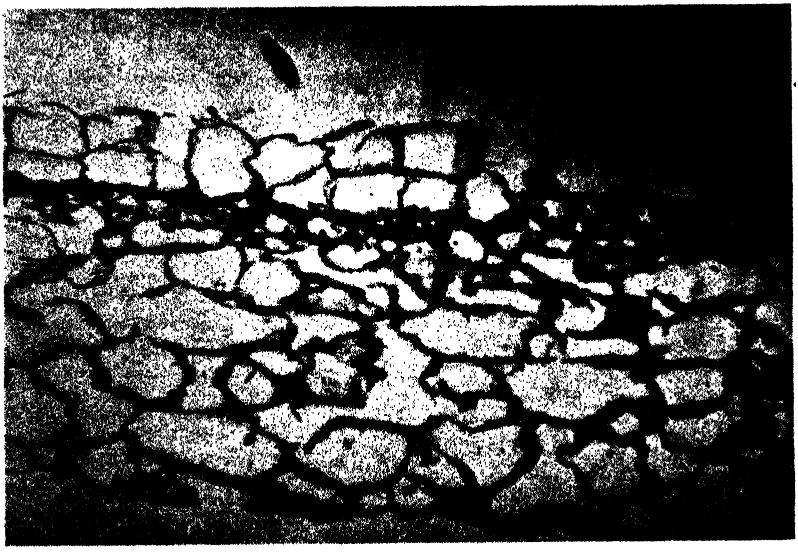

Fig. 1. Section through a white spot in a leaf of African Violet. The palisade layer from the center of the picture and to the left shows injury. That to the right is normal green tissue.

The drop in temperature occurred within 30 seconds after the application of ice water, and the injury was limited to the palisade layer, made up of comparatively small cells packed tightly together. Since these are the cells in which photo-synthesis occurs, they probably have the highest content of soluble sugars in the leaf, and are probably highly turgid under normal conditions. When a group of these cells is cooled suddenly to a much lower temperature those around them, it is possible that distillation and injury similar to that studied by Curtis (1) and Curtis and Clark (2) occurred. The rup-

ture of the cell walls of the injured area may have been caused by excessive water forced into the already very turgid cells of the cooled area by the much higher temperatures surrounding it. Since high temperatures were continuous over the rest of the leaf, it is quite possible that the cells which were giving up water to the cooled area could draw water freely from the rest of the cells of the leaf, or at least of the palisade layer. The slight osmotic gradient set up as a result of water loss was probably enough to bring about the replacement of this water before injury due to dessication occurred.

In ring spot, the same process could occur in a lesser degree. That is, only in a narrow band of tissue where the temperature gradient was steepest was the pressure great enough to cause rupture.

Production of similar injury by application of a cold knife shows that temperature differential, not drops of water, is the main requirement for producing leaf spot.

When hot water was placed on the leaf, a temperature increase of 30 degrees was brought about. This caused severe injury of the entire leaf directly under the hot water, mesophyll as well as palisade layer. Around the edge of this severely injured area was a ring of typical white leaf spot tissue. It is conceivable that the same process occurred as has been postulated for injury due to reduction in temperature suddenly over a limited area. That is, water distilled from the heated area may have been forced into the cooler area around the leaf so suddenly that the normal mechanism for transfer of water was too slow to prevent rupture of the cell walls due to excessive pressure from water within the cell.

Summary

Ice water on a leaf in the sun caused a localized 35 degree drop in temperature resulting in leaf spot. Contact with a cold knife also caused leaf spot. Hot water caused a 30 degree F rise in temperature of the leaf and very severe leaf injury, similar to natural leaf spot only around the edges. It may be that vapor pressure gradients due to sudden localized temperature differentials caused collapse of the palisade cells observed in Saintpaulia leaf spot. The light intensity to which the leaf is exposed determines the temperature differential between the leaf and the air, and therefore probably determines the "susceptibility" of the leaves to injury from excessively high or low temperature areas. Examination of Saintpaulia leaf spot showed localized collapse of the palisade layer, leaving all other leaf tissues apparently unaffected.

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Tip Curvature of Cut Gladioli

By T. M. WHITEMAN and W. D. MCCLELLAN, *U. S. Department of Agriculture, Washington, D. C.*

SINCE shippers of southern-grown gladioli question the desirability of loading the spikes horizontally in boxes because of tip curving en route, the bulk of cut gladioli is now shipped vertically in hampers or in boxes in which one end is removed. Of course, by using this method only one layer can be loaded per car. Increasing the tonnage of cut gladioli per car in shipments from the South might mean annual savings both in the number of railroad cars required and in shipping costs chargeable to the growers.

The general purpose of the tests reported here was to investigate the possibility of utilizing more cubic feet of space per car by loading horizontally, and, specifically, to determine the factors that tend either to promote or to inhibit tip curvature. At the outset it was decided to investigate the effects of light, the inherent tendency of plant tops to grow upward, and the influence of temperature on these effects.

In all of the following tests Picardy gladioli were cut early in the morning and only those of commercial tight-bud maturity with straight tips were used. They were bunched in lots of 10 spikes each. Except where noted, the bunches were held in water in a 50 degree F room for 3 or 4 hours before bunching and storing. The data for tip curvature were obtained by laying the spikes in a horizontal position and measuring the amount of curvature in angular degrees with a protractor.

AN EXPLORATORY TEST

It was observed that the tips of the horizontal bunches at 80 degrees F had begun to curve upward after 1½ hours in this position. There was no tendency of check bunches held vertically in light at either temperature to curve toward the light, nor was this light response noted in the 80 degree horizontal bunch. Since the lots in light at 45 to 50 degrees and at 80 degrees showed somewhat less curvature after 22 hours than those in the dark, it was thought either that the light had a retarding effect on the rate of curving or that the higher humidity in the boxes had speeded up curving in these lots. It was clear that temperature influenced the degree of curvature. Since the lots held in darkness showed notable curvature, it was also apparent that this upward tip movement was a response away from or opposed to gravity, *viz.*, apogeotropism. The tip curving that occurred while the bunches were horizontal continued during a subsequent 3-day holding period at 50 degrees during which time they were vertical in water (Fig. 1).

EFFECT OF TEMPERATURE ON CURVATURE AND ELONGATION

One test was designed to determine the influence of different temperatures on the amount of tip curvature of gladioli when held in lidded boxes in the horizontal position. Fig. 2 shows the values for this curvature, at the temperature indicated, measured in degrees for

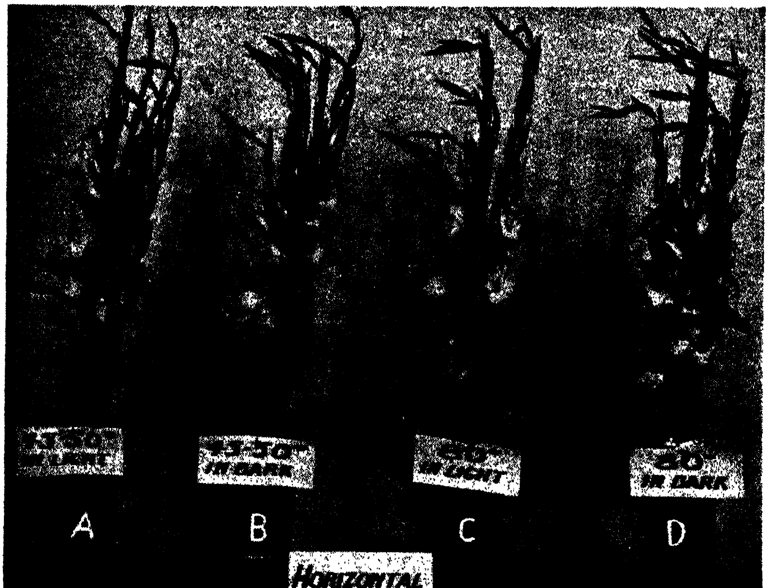

FIG. 1. Picardy Gladioli

All bunches in water for 3½ hours in vertical position at 50 degrees F. Then either vertical or horizontal out of water for 22 hours at the temperatures indicated, followed by a period of 3 days vertical in water at 50 degrees, after which they were photographed.

E—Stood vertically out of water 7 feet from a 200-watt lamp.

F—Stood vertically out of water in corner near window, daylight entering mostly at right angles to bunch.

A—In horizontal position about 4½ feet below a 200-watt lamp.

B—In horizontal position next to bunch A but in a heavy-lidded box.

C—In horizontal position in center of room, daylight entering only at right angles to bunch.

D—In horizontal position next to bunch C but in a heavy-lidded box.

Note: The butts of all bunches were wrapped with two thicknesses of wet newspaper covered by four thicknesses of dry newspaper until they were put in water at 50 degrees F.

the angle made with the horizontal. An average curvature of 20 to 25 angular degrees, or more, from horizontal is considered objectionable, so that from this standpoint the lot held at 32 degrees F was the only

one to fall in the "satisfactory" category. The fact that the 70 degrees F lot showed greater curvature than the lot at 80 degrees F, rather than less, is explained on the basis of the very high relative humidity in the 70 degree F room.

It was thought desirable to know how much elongation occurs and how fast it takes place at different temperatures. This elongation was observed to take place just below the tips of the spikes in the same region where curvature occurs when the spikes are placed horizontally. In these tests the relative humidity was approximately 85 per cent at all of the temperatures used and the spikes were held vertically, some in water and some out of water. Spikes held in water at 80 degrees F elongated about 6.5 cm after 2 days whereas those held out of water at 80 degrees elongated slightly more than 1 cm. Those held at lower temperatures (32, 40 and 50 degrees) elongated 1 cm or less during 5 days.

Effect of Light and Humidity

Table I shows the tip curvature of gladioli held horizontally out of water at 50 and 80 degrees F both in the light and in the dark. Those in the dark were in heavy lidded boxes whereas those in the light were about 6 feet below a 200-watt lamp. In this and in previous comparisons of gladioli held horizontally in the light with those held horizontally in lidded boxes in the dark it was shown that those in the boxes curved more than those in the light.

TABLE I—Tip Curvature from Horizontal, Expressed in Angular Degrees, of Cut Gladioli Held in the Light and in the Dark at 50 and 80 Degrees F

Hours After Storage	Curvature in Angular Degrees			
	50 Degrees F		80 Degrees F	
	In the Light	In the Dark	In the Light	In the Dark
19	21.2	25.6	31.9	71.8
43	22.0	40.6	44.9	90.6

In order to determine whether the bending of gladioli tips when the bunches are laid horizontally is due to the influence of humidity or light, the storage conditions stated in Table II were used. It appears from this table that light did not appreciably affect the bending of the tips and that the bunches under high humidity conditions curved more than those at low relative humidity at both 50 and 90 degrees F. Bunches 1, 2, and 3 (Table II), being horizontal at 50 degrees for only 17 hours, straightened out somewhat after standing vertically in water for 48 hours.

Weighting the Tips

In two tests the tips of cut gladioli were weighted with about 1 pound of newspaper and held horizontally in lidded boxes. After 1 to 3 days the papers were removed and the spikes placed vertically in water. When the spikes were taken from the boxes there was no tip

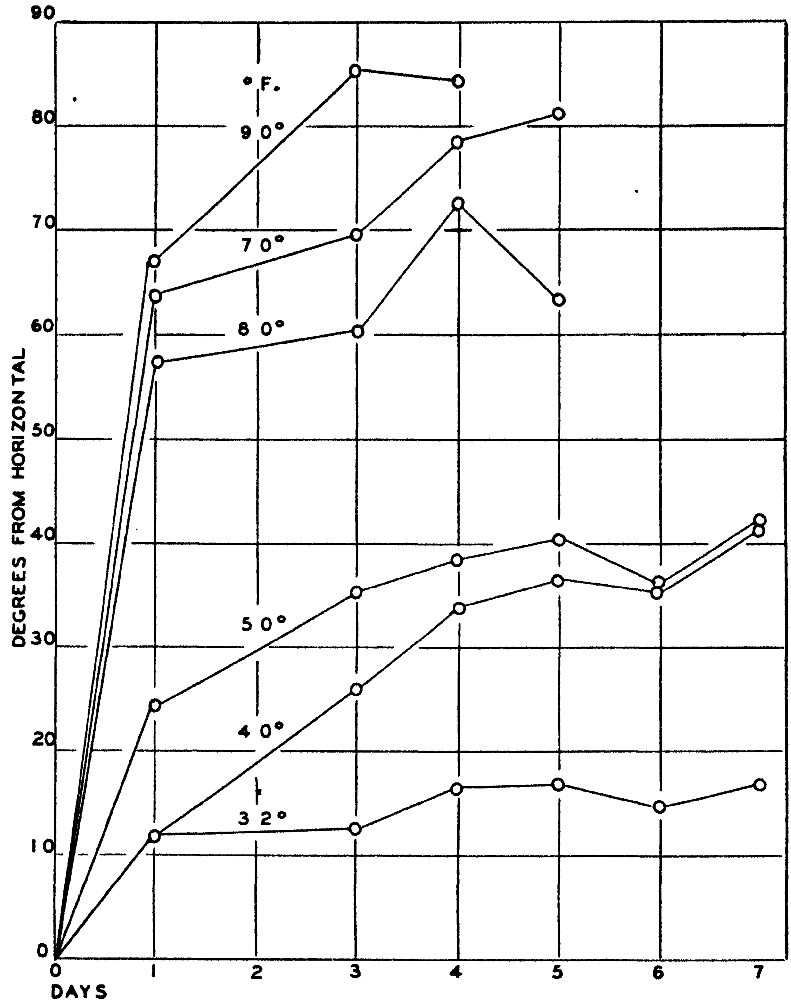

FIG. 2. Tip curvature of Gladioli after holding 1 to 7 days at different temperatures.

curvature but within an hour after they were placed in the vertical position curvature was noticeable and 1 to 3 days later the curvature amounted to 45 to 58 degrees.

EFFECT OF FORCED GROWTH AFTER CUTTING

This test was conducted to discover whether gladiolus spikes would elongate sufficiently while in a vertical position at 80 degrees F with a high relative humidity, to prevent any further growth when placed horizontally at a lower temperature. A temperature of 50 degrees was selected for the latter part of the treatment because of the probability

TABLE II—AVERAGE TIP CURVATURE FROM HORIZONTAL, IN ANGULAR DEGREES, OF GLADIOLI HELD HORIZONTALLY IN HIGH AND LOW HUMIDITIES AT BOTH 50 AND 90 DEGREES F FOR 17 HOURS AND SUBSEQUENTLY HELD VERTICALLY IN WATER FOR 48 HOURS

Bunch Number	Conditions of Storage: Temperature Degrees F	Relative Humidity	Position and Lighting	Original Curvature (Degrees)	Average Increase in Curvature Over Original—Degrees From Horizontal: After Storage for 4 Hours	7 Hours	17 Hours	After 48 Additional Hours in Water
1	50	82–85	On floor rack, covered with box lid. Dark.	15.3	5.4	11.4	23.7	5.5
2	50	82–85	6-foot distance from 200-watt bulb	16.5	13.2	18.4	22.2	5.9
3	50	—	Completely enclosed in heavy box. Probably high humidity.	14.4	9.9	13.0	29.1	19.8
4	50	55	Exposed to room atmosphere. Dark.	11.9	2.8	-1.4*	-11.9*	14.4
5	90	85	In 3×4-foot chamber. Dark.	5.0	51.8	57.1	53.7	56.2
6	90	60	Exposed to room atmosphere. Dark.	13.4	37.9	38.8	37.2	58.2

*Decrease in curvature was due to wilting.

that the top layer of the load in an iced refrigerator car may often be approximately 50 degrees.

The eight treatments to test the effect of forced growth after cutting are shown in Table III. Immediately after cutting these gladioli were bunched and put into the rooms without first being placed in water. Bunches 5 and 7 were the only two that gave curvatures sufficiently below the borderline zone to be considered satisfactory.

The degree of curvature of bunch 8 indicates what could be expected if gladioli were loaded horizontally for shipment, and the curvature of bunch 7 approximates what might occur under the present system of loading gladioli vertically in cars.

PARTIAL WILTING

It was thought that a certain amount of wilting previous to shipment might possibly prevent tip curvature to some degree, although it did not appear that this treatment would have a practical application.

Since temperatures of 36 and 50 degrees F may approximate those in the bottom and top layers, respectively, of iced refrigerator cars, a test was set up to determine the amount of tip curvature under these conditions. The 36, 50, and 80 degree rooms each had a relative humidity of 85 per cent. The bunches were not put in water before storing. Table IV shows that from the standpoint of tip curvature a treatment of 5 hours at 80 degrees was not long enough to allow sufficient growth to prevent undue curvature later (bunch 1). The behavior of bunches 2 and 4 indicates that 24 hours at 80 degrees reduced the degree of tip bending that occurred later when these lots were stood in water at 50 degrees. However, bunches 3 and 4 were discarded after 1 day in water because of advanced development of the blossoms, and wilting. After 1 day in water at 50 degrees bunches 1 and 2 were rated as "salable" and "salable at a discount," respectively, whereas after 3 days the ratings were "salable" and "not salable," respectively.

TABLE III—TIP CURVATURE (ANGULAR DEGREES FROM THE HORIZONTAL) OF CUT GLADIOLI AS INFLUENCED BY HOLDING UNDER THE CONDITIONS INDICATED

Successive Treatments Given Individual Bunches at Temperatures of 50 and 80 Degrees F.	Curvature Observed at Stated Periods After Start of Test			
	21 Hours	29 Hours	96 Hours*	120 Hours**
Bunch 1				
4 hours at 80 degrees—vertical, out of water 66 hours at 50 degrees—horizontal, out of water 50 hours at 50 degrees—vertical, in water (Tips weighted for first 70 hours)	—	—	27.8	23.3
Bunch 2				
4 hours at 80 degrees—vertical, out of water 66 hours at 50 degrees—horizontal, out of water 1 hour at 80 degrees—vertical, out of water 49 hours at 50 degrees—vertical, in water (Tips weighted for first 70 hours)	—	—	32.7	28.0
Bunch 3				
3 hours at 80 degrees—vertical, out of water 67 hours at 50 degrees—horizontal, out of water 50 hours at 50 degrees—vertical, in water	—	—	29.3	21.9
Bunch 4				
5 hours at 80 degrees—vertical, out of water 65 hours at 50 degrees—horizontal, out of water 50 hours at 50 degrees—vertical, in water	11.0	—	21.7	20.4
Bunch 5				
29 hours at 80 degrees—vertical, out of water 41 hours at 50 degrees—horizontal, out of water 50 hours at 50 degrees—vertical, in water	13.7	13.7	15.3	15.1
Bunch 6				
29 hours at 80 degrees—horizontal, out of water 41 hours at 50 degrees—vertical, out of water 50 hours at 50 degrees—vertical, in water	21.5	25.6	40.0	46.2
Bunch 7				
70 hours at 50 degrees—vertical, out of water 50 hours at 50 degrees—vertical, in water	7.5	—	13.7	16.1
Bunch 8				
70 hours at 50 degrees—horizontal, out of water 50 hours at 50 degrees—vertical, in water	—	—	28.0	30.7

*The last 26 hours were in water.
**After a total of 50 hours in water.

DISCUSSION AND SUMMARY

Elongation of gladiolus spikes took place at temperatures of 32, 40, 50, and 80 degrees F, the amount increasing with an increase in temperature. The tendency of the tips to curve upward was due to apogeotropism primarily and not to light. This response to apogeotropism was retarded by both low temperature and low humidity. It was noted, however, that even at low temperatures apogeotropic factors usually had sufficient latent influence on spikes placed horizontally to effect rapid tip curvature when the spikes were afterward placed vertically in water, at higher temperatures.

TABLE IV—TIP CURVATURE FROM HORIZONTAL, IN ANGULAR DEGREES, OF CUT GLADIOLI AFTER 5 AND 24 HOURS AT 80 DEGREES F, IN A VERTICAL POSITION OUT OF WATER; A SUBSEQUENT PERIOD OF 7 DAYS AT 36 AND 50 DEGREES WHEN HORIZONTAL; AND FINAL HOLDING PERIODS OF 1 AND 3 DAYS IN WATER AT 50 DEGREES

Bunch Number	Hours at 80 Degrees F.	Temperature at Which Held for 7 Subsequent Days	Curvature After 1 or 3 Subsequent Days in Water at 50 Degrees F.	
			1 Day	3 Days
1	5	36	18.6	25.1
2	24	36	13.6	15.7
3	5	50	33.8	—
4	24	50	23.6	—

Turgid spikes curved when placed horizontally even under conditions of low temperatures and low humidity whereas less turgid spikes curved more slowly when placed under these conditions. However, partial wilting of spikes did not appear to be a feasible method of preventing curvature although it was obvious that when spikes were held out of water at 80 degrees F in a vertical position for about a day before holding them horizontally, later curvature development was minimized. Of course, flower development is speeded up by this method and it is doubtful whether it could be adapted to commercial use.

Fermate and Its Effect on Rooting of Geranium Cuttings[1]

By Harold E. White, *Massachusetts Agricultural Experiment Station, Waltham, Mass.*

Treatment of seeds, lily bulbs, woody and herbaceous cuttings with growth substances combined with fungicides has been reported by several workers.

Fermate (ferric dimethyldithiocarbamate) is one of the newer fungicides which has been reported as a stimulant for rooting of cuttings of chrysanthemums, poinsettias, and carnations, as well as being an effective control of fungous rots encountered in plant propagation. Information so far presented has not been too well substantiated with experimental data as to the merits of Fermate in treatment of cuttings of greenhouse ornamental plants.

The tests with geranium cuttings reported here were made with Fermate and growth substances to determine the effect of such treatments on rooting of cuttings and occurrence of rot diseases.

Materials and Methods

The basal ends of geranium cuttings were dipped in dry powdered Fermate, in a Fermate-indolebutyric acid mixture, in a Fermate-naphthaleneacetic acid mixture, and in Hormodin No. 1-Fermate mixture; and Fermate was applied as a dust to the entire cutting.

The indolebutyric and naphthaleneacetic acid and Fermate combinations were prepared at a concentration of one part of growth substance to 5,000 parts of Fermate. The acids were dissolved in sufficient 95 per cent alcohol to wet thoroughly the Fermate used as a carrier. After the alcohol was evaporated the Fermate was well powdered and stored in a tight, light-proof container. Hormodin Powder No. 1 (Merck) containing indolebutyric acid was combined with Fermate in proportion of 10 parts of Fermate to 90 parts of Hormodin No. 1 powder, by weight.

There were 100 cuttings used in each of the six treatments. One experiment was conducted in a commercial range on cuttings taken from inside-grown geranium plants. The second experiment was conducted at Waltham on cuttings taken from field-grown plants. Both tests were started on September 12 and final data on rooting taken on October 10. Bottom heat was applied to the sand to maintain a 60 degrees F temperature, when necessary, with an air temperature of 50 degrees F.

Results

Experiment No. 1:—This test was conducted on inside-grown cuttings in a commercial range and results of the various treatments are shown in the table.

The amount of rot disease was not great under conditions of this test, and while some loss occurred in both treatment and untreated cuttings such losses were so low that no conclusions can be made as to the merits of Fermate as a fungicidal treatment for cuttings.

[1]Contribution No. 586, Massachusetts Agricultural Experiment Station.

When Fermate was applied as a dust to the entire cutting, root formation was very poor with only 70 per cent rooted. The roots formed on cuttings treated with Fermate alone were one-third shorter in length and much thicker in diameter than the roots in any of the other treatments.

When Fermate and growth substances were applied to cuttings as a combined treatment, roots formed on these cuttings were greater in number and longer than roots on cuttings given separate treatment with Fermate or growth substance.

Experiment No. 2:—Here the same treatments as outlined for Experiment No. 1 were applied to cuttings taken from field-grown plants at Waltham.

The data in Table I show that rot disease was very prevalent causing a loss of 14 per cent in untreated cuttings. Cuttings which had

TABLE I—The Effect of Fermate on Rooting of Geranium Cuttings

Treatment	Rooted (Per Cent)		Unrooted (Per Cent)		Rotted (Per Cent)	
	Inside-grown Plants	Field-grown Plants	Inside-grown Plants	Field-grown Plants	Inside-grown Plants	Field-grown Plants
None	88	64.00	12	21.50	0	14.50
Fermate-Indolebutyric Acid	95	80.59	2	11.76	3	7.65
Fermate-Naphthaleneacetic Acid	92	73.73	6	12.18	2	14.09
Fermate-Hormodin No. 1	96	78.89	4	12.59	0	8.52
Hormodin No. 1	89	81.37	8	10.45	3	8.18
Fermate	96	63.77	4	23.51	0	12.72
Fermate Dust	70	52.00	30	22.50	0	25.50

Fermate dust applied to the entire cutting suffered a loss of 25 per cent due to rot. When Fermate was applied to the basal ends of cuttings, loss from rot was 12 per cent as compared to 14 per cent for untreated cuttings. Fermate combined with growth substances and applied to cuttings gave the lowest percentage of losses from rot.

The response of cuttings treated with Fermate-growth substance combinations was much more pronounced in this experiment than in the previous one. The treated cuttings rooted 80 per cent in comparison to 64 per cent for checks or untreated cuttings. Fermate applied alone as a dust to the entire cutting was the poorest with 52 per cent rooted. When basal ends of cuttings were treated with straight Fermate, the percentage rooted was the same as for no treatment. Here, as in Experiment No. 1, roots formed on cuttings treated with Fermate-growth substance combinations were more numerous and of greater length than where Fermate alone was used.

Conclusions

In these experiments, Fermate alone when applied to geranium cuttings did not reduce losses from cutting rot diseases. When cuttings were treated with growth substances in combination with Fermate a greater percentage of such cuttings rooted, and losses from rot diseases were significantly reduced. Such combinations of Fermate and growth substances gave more and longer roots on cuttings.

One important fact shown by the results of these tests is that culture of stock plants under glass is an effective means of reducing losses from rot diseases of geranium cuttings. Previous experimental work at Waltham (1) in propagation of geraniums has emphasized the importance of inside culture of stock plants.

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The Effect of Spacing of Gardenia Plants on Yields of Flowers

By F. F. WEINARD and J. R. KAMP, *University of Illinois, Urbana, Ill.*

GARDENIAS (McLellan No. 23) were propagated in the spring of 1943 and benched that summer. They began blooming in the fall and production records were kept continuously from that time until they were removed from the bench on June 1, 1945. The records therefore covered two complete blooming seasons.

Series 1:—Plants were spaced three across a 4-foot bench, with rows 14 inches apart. No change was made the second season. There were two such plots on adjoining benches. Each plot contained 36 plants, not including guard rows.

Series 2:—Plants were spaced three across the bench with rows 24 inches apart. No change was made the second season. There were two plots of this treatment also, each containing 18 plants, in addition to guard rows.

Series 3:—Plants were set three across the bench, in rows 14 inches apart. On July 5, 1944, alternate rows were removed, so that the remaining rows were 28 inches apart the second season. Duplicate plots contained 36 plants each the first year, and 18 plants the second year, exclusive of guard rows.

TABLE I—YIELDS OF GARDENIAS WITH VARYING SPACING

Season	Average Number of Flowers Per Plant	Average Number of Flowers Per Square Foot of Bench
	Series 1	
1943–44	16.9	10.9
1944–45	28.6	18.4
Two seasons	45.5	29.3
	Series 2	
1943–44	31.0	11.6
1944–45	44.2	16.6
Two seasons	75.2	28.2
	Series 3	
1943–44	18.3	11.6
1944–45	50.0	15.6
Two seasons	—	27.3

Considering the increased yields obtained in the second year, it is suggested that gardenias should be allowed at least two seasons in the bench. Through a 2-year period the total yields per square foot of bench space varied only slightly, regardless of the spacing of the plants. The lower cost of planting and the greater ease of upkeep with the wider spacing are points in favor of this method.

The Point of View in Pomological Instruction

By DILLON S. BROWN, *University of Illinois, Urbana, Ill.*

THIS paper is an outgrowth of the writer's efforts in planning a reorganization of the introductory course in fruit growing at the University of Illinois, the course recently having been placed in his charge. In order to crystallize the writer's ideas and points of view, free of outside influence, the first draft of this paper was written purposely without reference to papers and committee reports on horticultural teaching which were known in a general way to have been published in the Proceedings of this Society. Those publications were then examined critically to see in what way this writer's ideas were related to those previously expressed. As it possibly should have been expected, none of the writer's ideas on teaching are new, all of them having been expressed previously in one way or another. The only claim to originality which the writer can justify is the relative emphasis and application given to such ideas or points of view.

Only a few of the papers on horticultural teaching are referred to in this paper. Those interested in reviewing in more detail the older papers will find most of them scattered throughout the Proceedings of this society from volume 8 (the report of the 1911 meeting) through volume 21 (the report of the 1924 meeting) with an additional few, including brief committee reports, in volumes 32 through 39.

Essentially, only two questions were in the background of the older publications on horticultural teaching, "what to teach" and "how to teach it". These are the same questions which had to be answered in formulating a point of view from which to reorganize the introductory course herein discussed.

For the pomologist, the fundamental concept which underlies the question of what to teach is expressed in the statement: Fruits are food. The basic nature of this concept should be self-evident, since the ultimate justification for growing fruits, either commercially or for the home, is their use as food. If, for example, man did not eat apples or apple products, or as an alternative feed them to his livestock, there would be no apple-growing industry.

Granting this basic premise, the point of view may be amplified by the concept that the fruit grower is concerned with the production of fruit of high *quality* and good *condition*, that is, a food of high physiological and psychological value to the consumer (quality) and of sufficiently attractive appearance (condition) to stimulate its use. Further, and of equal importance to either the commercial or the home fruit grower, the production of the fruit must be *profitable*.

The problem of what to teach thus rests on the concept that fundamentally the objective of a fruit grower is the production of a food of high quality and good condition at a profit. It is an objective which seems most frequently to have been taken merely for granted or overlooked, not only in the introductory courses but in the advanced courses as well. Of course, the actual subject matter used in presenting this concept may be approached from the one or the other, or both, of two points of view: (a) the methods (arts and skills) used in fruit pro-

duction — the "what to do" or "how" of fruit growing — and (b) the fundamentals of plant behavior (science) — the "why" of fruit growing. It is the relative emphasis placed on these two points of view concerning the subject matter which will govern the actual method or procedure by which fruit growing is taught.

Much of the early discussion on horticultural teaching revolved around this question of the emphasis to be placed on the practical and the scientific aspects of fruit growing (1, 4, 5, 6, 7, 8, 9, 10, 12, 15, 16). In general, earlier writers were in accord that the major emphasis should be on the side of the fundamental or scientific background, as a basis for understanding, interpreting and solving practical problems in fruit growing. As inferred by Barnett (2), however, the question is still open as to how successfully most instructors of horticulture have blended properly the practical and the scientific in their teaching. In any case, it seems certain that whatever the weight given to the two phases of the subject matter, the fundamental point of view that fruits are food has been insufficiently emphasized.

In reorganizing the introductory course at Illinois, primary emphasis has been placed on the fundamentals underlying practical fruit growing. The arts and skills, the practices of fruit growing are used to illustrate and demonstrate the dynamics of the fundamentals and to give solidity to scientific principles or hypotheses which otherwise might remain pure abstractions in the student's mind. Throughout the course the objective is to blend the scientific and the practical, while pointing always toward the goal of the profitable production of quality fruit — a food.

As to the point of view on the problem of how to teach, the following subject-matter outline will serve as a basis for discussing some of the methods contemplated or being used in the course.

Introductory Fruit Growing

A. The value of fruits
  1. Fruits as food
  2. Quality of fruits
  3. Condition of fruits

B. Fruit development
  1. Buds
  2. Flowers and fruit setting
  3. Fruits

C. Fruit growing
  1. Propagation
  2. Planning and planting
  3. Training and pruning
  4. Soil management
  5. Pests and their control

D. Fruit handling
  1. Harvesting
  2. Grading and packing
  3. Transportation and storage
  4. Marketing.

The laboratory is the basic medium of instruction used in effecting an answer to the question of how to teach. The point of view is one of building the course around the laboratory exercises, rather than the more common one (1, 2, 3, 5, 6, 7, 8, 12, 15) of using the laboratory to supplement lectures, discussions and text assignments. Formal lecturing is to be avoided, the little which is done to be incorporated as an integral part of class discussion periods or in the presentation of purely demonstrational and visual-aid materials. The discussion periods are intended to direct, clarify and solidify the interpretations made by the student on material studied in the laboratory. The satisfactory blending of the fundamental and the practical phases of fruit growing is attempted by permitting the student, in effect, to teach himself by handling, observing and interpreting selected demonstrational materials. The value of the laboratory method of instruction, in which the student is given the opportunity to examine plant materials and to observe plant behavior, is clearly indicated by a recent study of methods of teaching general botany (13).

The laboratory work is formulated around a series of units or exercises. Several class periods may be required to complete some of the exercises, the time required depending upon the amount of closely related material which it is reasonable to consider as a unit. In those instances in which it would be too time-consuming to require each student (or group of students) to do all portions of an exercise, the responsibility for the various parts is divided among groups in the class and the results of the observations of each group are made available to the class as a whole. Written reports on each exercise are required, the nature or style of the report being determined by specific directions describing the work to be done. In all instances the student is asked to make certain conclusions of his own from the observations and work done. In addition, special problem questions are appended to each exercise to be answered as a part of the report. These questions are for the most part designed to give the student practice in applying fundamental information in the solution or explanation of practical problems, many of the questions being based on actual inquiries from commercial and home fruit growers. The use of specific directions for laboratory work and the requirement of written reports has been recommended frequently (1, 6, 12).

The course is introduced with a consideration of the value of fruits as food and the importance of the profitable production of fruit of high quality and good condition (Section A of the outline). This approach — presenting at the beginning the fundamental point of view — establishes the goal toward which the remainder of the course can be directed.

It was particularly interesting to the writer to find that Colby (6) in presenting an outline of this same course in 1924 included "The value of fruits as food" under an introductory item, "General considerations". Today, the nutritional importance of fruits is more widely recognized and fruits in general are in greater use, less of a luxury food, than they were 20 years ago. It is therefore possible now to give a more satisfactory consideration of and to place greater emphasis on

the food value of fruits. Just as indicated by Colby, that consideration can well be placed in the initial phases of the course, the only difference being that today the consideration of fruits as food may well constitute a greater portion of the introductory material.

Since the course is offered in the fall term, apples are available for demonstrational purposes in the introductory exercise. For example, the quality and nutritional aspects of fruits can be illustrated through the use of mature and immature apples of several different varieties, supplementing the demonstration samples with representative data as to the composition of those varieties at different stages of maturation. At the same time by considering several varieties, the general idea of varietal differences and the importance of variety selection can be introduced. While keeping the emphasis on the quality and condition factors, a limited amount of work on apple variety identification can be begun, to be continued throughout the course when time permits, as much for the purpose of merely keeping the student aware, through example and contact (both external and internal), of an end product of fruit growing as for any real value a familiarity with varieties may be to him as a consumer or producer.

When given in the fall, it also is timely as a part of the introductory material to move up the consideration of harvesting from the fruit-handling section (Section D, point 1, of the outline). The student can then see at first hand a representative fruit on the plant. Actual practice in harvest will give him a personal contact with fruit and demonstrate the important part which careful harvesting plays in the production of fruit of good condition and quality. If the student orchard is organized on a demonstrational basis, including such demonstrations as the effects of thinning, harvest sprays, pruning and fertilizers, the student can be shown examples of the end result of some of the orchard practices which later will be studied in more detail. It is also possible at the harvest time to raise questions on fruit development, the answers to which will be brought out in succeeding exercises. For example, such basic questions can be raised as, "Here is an apple on the tree, what is its history; how did it get there; what factors have influenced its development?"

A consideration of the over-all seasonal picture of fruit development (Section B) then naturally follows, beginning with the bud and ending with the mature fruit. The morphological and physiological bases of fruit development are presented. Both fresh and preserved materials, including buds, flowers and fruits of various kinds, are used in the laboratory. For example, the student can get a picture of the periodic development of peach fruits by actually measuring preserved specimens which represent stages in the various growth periods. A comparable series on the apple will furnish a contrast.

The exercises on fruit development supply the student with an insight into the fundamental materials of fruit growing, the fruits themselves. They furnish the opportunity for raising questions as to production practices which might influence fruit development and enable a grower to reach the goal of quality fruit production. Some practices can be presented in an introductory way and so establish a link with

a more detailed consideration of such practices under the section on fruit growing. Under that section (Section C) full use should be made of demonstrational material in the orchards, vineyards and the small fruit plantations (the outdoor laboratories), and in the greenhouse. For example, demonstration material illustrating the methods and effects of training and pruning of fruit plants should be available in the orchard. Such material can be used most effectively by giving the students some practice in pruning so that through the actual operation on and the handling of the plants a consideration of the principles of pruning and the fundamental differences and similarities in response of the various kinds of fruit become more concrete.

At this point it should be pointed out that it is neither necessary nor desirable to consider the various kinds of fruit as widely separated entities. When several different fruits are considered concurrently, similarities and differences between them, their structure, habits of growth and responses to production practices can be used to advantage for contrast and emphasis in discussing and demonstrating the fundamentals of plant behaviour and their relation to production practices. Chandler (5) evidently had something of this point of view in stating that courses in special crops, such as small fruits, were not essential.[1]

The field demonstration material can well be supplemented by other materials in the greenhouse. Since much of the time spent in courses such as this comes usually during the dormant season, the greenhouse offers the opportunity to show the students actively growing demonstrational materials. For example, in connection with exercises on soil management, representatives of the various agronomic crops used as orchard covers can be grown somewhat satisfactorily in the greenhouse. By including some fertilizer differentials in connection with such crops the student is given observable material which will make more concrete a discussion of soil management which otherwise becomes quite abstract. Additional demonstrations are possible with some of the small fruits especially, growing in sand or soil cultures at different fertility levels.

Following the exercises on fruit growing the section on fruit handling (Section D) affords the opportunity to focus the student's attention in the final stages of the course again quite directly on the theme of quality fruit. Because of their availability, apples again can supply most of the demonstrational material in connection with exercises on grading and packing, and storage. These phases can be tied back into the preceding consideration of production practices by grading and packing apples harvested from the different demonstrational blocks in the orchard, so as to give the student a first hand comparison of fruits, say, from pruned and non-pruned trees, or from trees lightly and heavily fertilized with nitrogen. The important relationships between production practices and the development and handling of fruit of good quality and condition can be presented more clearly and effectively in the laboratory than in the lecture room.

Since the notation of a course as "introductory" sometimes infers

[1]Chandler expresses an opposite view, however, in the preface (page 5) of his book: Deciduous Orchards, Phila., Lea and Febiger, 1942.

that there are "advanced" courses following, the relation of the introductory course discussed above to succeeding courses will be indicated. At Illinois, the introductory course is general in that it gives an overall picture of fruit production. The intent is to present the picture rather completely, in the most essential details, so that the student will obtain a unified concept of fruit growing. The course must be complete and detailed enough to be of real value in furnishing a reliable background in fruit growing for those students in the general and the vocational agriculture curricula who normally do not elect additional courses in the subject. When the fruit growing course is made adequate for a sound training of students in those curricula, it almost automatically has been made highly satisfactory, at the same time, as a beginning for those students who are majoring in the subject.

There need be no question of the introductory course being so detailed that it will detract from advanced courses, a criticism which was raised by some departments included in the survey reported by Van Meter (14). Rather, as Bradford (4) has indicated, if an advanced course cannot carry ahead from the point at which the beginning course leaves off, then that advanced course is non-essential. For the pomology major, the introductory course defines the goal in fruit production and establishes the pattern, the master blueprint, to be followed in reaching that goal. The advanced courses then are limited to restricted areas within that pattern, covering the subject matter in those areas more critically and in greater detail, but still pointing to the goal of the profiable production of quality fruit.

Probably no more than four or at the most five additonal courses in fruit growing need be required at the undergraduate level in a pomology curriculum. One of these should be a production course covering points 1, 2, 3 and 4 under Section C in the outline of the introductory course. The matter of pest control (point 5 under C), especially from the standpoint of the sprays and spray materials used, is sufficiently involved to warrant its presentation in a separate course at the advanced level. A third course should cover the points under Sections A and B, the value of fruits and fruit development, and to some extent the points under Section D, fruit handling, through a consideration of the quality (value as food) of fruits as determined by fruit development (maturation) and fruit handling (ripening). This course would tie into the production course by overlapping to some degree in the harvesting aspects of fruit handling. A fourth course in fruit (and vegetable?) marketing should deal with the more strictly economic aspects of fruit handling. A possible fifth course has a place in the middle ground between the fruit development and the marketing courses as a course more strictly concerned with fruit handling. For consideration in such a course are the matters of packages for fruits (and vegetables?) in connection with grading and packing, storage, and marketing problems, a subject which deserves special treatment because of the importance of grades, packages, transportation and storage in the job of getting quality fruit to the consumer in good condition.

It is recognized that the plan herein outlined for the introductory course and its relationship to advanced course may not fit precisely the

needs or be adaptable to the personnel of all departments of horticulture. It is believed, however, that the plan is sufficiently flexible, that it might serve as a pattern for a standardization of pomological courses along rather broad lines. The need and desirability of having a definition of at least minimum standards for horticultural instruction has been brought to the attention of this Society on other occasions (10, 11, 16). It does seem that whatever the courses or curricula deemed necessary, they all should at least be organized to present the fundamental point of view that fruits are food. From the introductory course to the most advanced the instructional job is essentially one of teaching the hows and whys of the profitable production (and delivery to the consumer) of fruit of high quality and good condition.

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American Horticultural Science Today

(Presidential Address)

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The major objective of this survey on *American Horticultural Science Today* is to establish a frame of reference from which change or progress may be measured or estimated. The time is auspicious for such an undertaking, because no one would question that our science is entering an era of unprecedented development and service to knowledge and human welfare. A description of the present structure of their science should prove valuable not only to horticulturists but also to scientists in related fields; how valuable it will be depends upon the accuracy and completeness of the picture which is drawn.

If the picture is not accurate and complete, the fault will not be that of the more than 50 leading horticultural scientists who have contributed to its delineation. Their response to requests for information has been prompt and whole-hearted; many have given encouragement, and have expressed opinions that the project is worth while. Their co-operation and enthusiasm are hereby very gratefully acknowledged.

Our science, like any higher organism, lives by expanding its body of knowledge and by increasing its members. It must learn and it must teach. Research is important not only for the service it can render the practice or art of horticulture, but also for the validity and vitality it imparts to instruction, the means by which the hands of the science are multiplied.

The Scope of American Horticultural Research

The answers received from the questions included in this survey represented more than 80 per cent of all American horticultural scientists, and therefore may be considered as a fully representative sample. Responses from the Dominion of Canada were not sufficiently numerous to represent that country adequately, as a random sample; because they had many characteristics in common with those from the United States, however, it may be assumed that horticultural science in Canada is similar to that in the United States, and is fairly represented by those who responded. No replies were received from countries south of the border.

The responses received indicate that research in progress is organized under more than 1500 projects, about equally distributed between fundamental studies, or those in which the objective is to understand the nature of processes, responses and relationships among horticultural plants and the conditions surrounding or acting upon them, and practical tests, in which attempts are made to effectuate improvements in practices, methods, plant materials, or products, by any practicable means or procedures. It is admitted that the project is a variable measure of research, and that classification of projects as fundamental and practical must be arbitrary to a considerable extent; the project, however, is generally understood to be a unit with a

fairly definite major objective, and most horticulturists who replied assigned their projects without extensive reservations to one category or the other, although certain ones admitted difficulty in classifying certain experimental studies in this respect.

The range and distribution of projects listed, with respect on the one hand to the horticultural materials and on the other hand to the phase of horticultural science under study are shown in Table I. The numbers in the various categories do not necessarily indicate actual numbers of projects, because the projects as listed in many cases included several kinds or species of plant material, or several of the aspects of study which were taken arbitrarily as a basis for analysis. Each number in the table simply indicates the number of times the project titles mentioned different phases of study on the various crops or groups of plant materials.

On this basis, the range of horticultural research is indicated to be very wide, both as to the kinds and species investigated and as to the aspects or phases of study. Seventy-nine kinds of plant materials or crops are under investigation, in addition to others which might be included in the major groups; 36 fairly distinct phases of study were used as a basis of analysis, and it is apparent that investigations on major crops or groups include most of the phases named. The classification of the studies, let it be emphasized furthermore, is not a very detailed one: cultural methods in the table, for example, include such widely different topics as spacing, time of planting, cultivation, pruning, thinning by mechanical or chemical means, and pre-harvest spraying; physiology includes plant responses to various influences, such as blossom bud formation, fruit set, growth, formation and distribution of synthesized products, maturation, and other functions, in response to the entire range of environmental conditions.

The distribution of studies under the different categories, while showing emphasis upon some particular crops or aspects of study, on the whole is a fair one. As is to be expected at the end of a war, during which food production was rightly emphasized, a great proportion of our research energies are being expended upon the food crops. Fruits, nuts, and vegetables account for 84 per cent of all researches reported from the departments of horticulture in the various land-grant colleges and state agricultural experiment stations; among individual crops, apples, potatoes, peaches, grapes, tomatoes, beans of several kinds, sweet potatoes, and strawberries head the list in descending order, with apples receiving 7.4 per cent of our research attention. Among ornamentals, which together account for approximately 15 per cent of research by horticulturists, roses, indoors and out, receive nearly 11 per cent of the attention paid to this general group.

Genetics and breeding projects, cultural methods, variety tests, physiological, fertilizer, nutrition, storage and handling, soil management, ecological, and propagation studies comprise more than two-thirds of the research studies reported; the first named group represents 13 per cent of the total. Appreciation, utilization, and economic aspects of horticulture received least attention.

The inclusion of Cinchona, coffee, and medicinal plants among horticultural plant materials will occasion no surprise; assays for alkaloid content of drug and insecticidal plants, however, and the metabolism of antibiotic and plant pathogenic microorganisms, respiratory enzymes and volatile products in fruits, the relation between internal structure of leaves and photosynthetic activity, and the use of ultraviolet radiation in identification of virus diseases might be considered as extending the bounds of horticultural research, though not beyond its capacity to occupy, as we shall see later. Most of us take for granted that the present-day horticulturist is perfectly at home in researches on such subjects as the factors influencing fruit shape and color, and the content of vitamin or flavoring substances; metabolic efficiency and water economy, cytological types of plants or varieties, anatomical relations to fruiting, lethal incompatibility between clonal stocks and certain fruit varieties, suitability of ornamental plants for camouflage, and cation-boron relations in plant nutrition.

The plant materials and topics in Table I are taken from replies received from horticulturists in state colleges, universities, and agricultural experiment stations, as has been mentioned before. Research in the Division of Fruit and Vegetable Crops and Diseases of the United States Department of Agriculture was not included, because the scope and organization of its projects is somewhat different from those in the departments of horticulture in state agricultural experiment stations. A brief sketch of research on horticultural crops in that Division, quoted from a letter from Dr. J. R. Magness, is included here, to make our picture of the research phase of American horticultural science more complete.

"The work of this Division in the horticultural field covers a wide range of activities with fruit, nut, ornamental and vegetable crops including potatoes. National headquarters are maintained at the Plant Industry Station, Beltsville, Maryland, but we also have field stations and field laboratories in a large number of States, and cooperative workers at many of the State Experiment Stations. A listing of active projects would be very voluminous since I believe we have about 400 at the present time. Thus I am not including the list but if you are anxious to have them I can furnish you with the titles.

"Most of our work is organized on a crop basis. Our major subdivisions are as follows:

1. Deciduous fruit investigations
2. Citrus and subtropical fruit investigations
3. Nut crop investigations
4. Vegetable investigations
5. Potato investigations
6. Floricultural and other ornamental crop investigations
7. Transportation and storage investigations with fruits, vegetables and ornamental crops

"The field work under each of the main subdivisions covers production practices, breeding, and diseases. In the workers on each crop of plants we have men whose primary training is in the field of horticulture, plant pathology, plant physiology and genetics. Thus we

TABLE I—RESEARCH PROJECTS IN HORTICULTURE, CLASSIFIED AS TO CROPS OR PLANT MATERIALS AND TO PHASE OF STUDY

Crop	Anatomy	Appreciation	Cultural Methods	Cytology	Disease Control	Ecology	Entomology	Experimental Method	Fertilizer Tests	Genetics and Breeding	Insect and Rodent Control	Irrigation and Soil Moisture	Labor Economy	Management	Market Grades	Marketing	Morphology	Nutritive Quality	Nutrition	Pathology	Physiology	Processing	Propagation	Quality	Rootstocks	Seed Production	Soil Adaptation	Soil Conservation	Soil Management	Soilless Culture	Storage and Handling	Taxonomy	Utilization	Varieties	Weed Control	Winter Injury, Hardiness	Total
Fruits*	4	—	13	3	9	4	—	5	12	5	11	3	1	—	—	4	4	6	15	7	22	13	5	1	10	—	3	1	11	—	18	1	—	24	1	5	221
Almond	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Apple	—	—	17	1	3	—	—	—	3	7	—	1	—	1	—	—	1	—	10	7	11	—	—	3	8	—	—	1	5	—	7	—	—	5	—	1	92
Apricot	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Avocado	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	3
Blueberry	—	—	4	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	1	—	—	—	2	—	—	—	—	2	—	1	14
Cherimoya	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	2
Cherry	—	—	1	—	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	—	—	—	2	—	—	1	—	3	—	—	13
Citrus	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	—	—	—	—	—	1	—	—	2	—	—	7
Cranberry	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	4
Grape (15 unclassified)	—	—	4	—	1	—	—	—	1	2	—	—	—	—	—	—	—	—	1	—	—	2	—	1	2	—	2	—	1	—	—	—	1	3	—	—	36
Litchi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Mango	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	3
Nectarine	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Papaya	—	—	1	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Peach	—	—	6	—	1	1	—	—	2	9	—	—	—	—	—	—	—	1	3	2	—	—	1	—	3	—	—	1	5	—	—	1	—	6	—	2	44
Pear	—	—	—	—	1	1	—	—	—	2	—	—	—	—	—	—	2	—	—	2	—	—	—	2	—	—	—	—	—	—	2	—	—	1	—	—	13
Persimmon	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	1	—	—	—	—	1	—	—	6
Plum and prune	—	—	2	—	1	—	—	—	—	4	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	3	—	—	12
Small fruits	—	—	5	—	2	1	—	—	1	8	1	2	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	8	—	2	32
Strawberry	—	—	1	—	—	—	—	—	2	9	—	1	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—	1	—	—	—	—	1	—	1	19
Nuts	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	4	—	—	7
Filbert	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2
Macadamia	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	3
Pecan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	3
Tung	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Walnut	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	3
Cinchona	—	—	1	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Coffee	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Vegetables*	2	—	16	1	4	10	2	4	18	14	6	13	1	—	3	2	4	11	13	2	14	14	1	7	—	5	4	1	14	1	15	—	—	29	6	1	238
Asparagus	—	—	—	—	—	—	—	—	1	3	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Beans	—	—	3	—	1	—	—	—	4	8	—	—	—	—	—	—	—	—	1	—	1	1	—	1	—	—	—	—	—	—	—	—	—	1	—	—	21
Beet	—	—	—	—	—	1	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Broccoli	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	3
Brussels Sprouts	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Cabbage	—	—	—	—	—	1	—	—	—	3	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	7
Cabbage, Chinese	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Carrot	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	2

Cauliflower	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Celery	—	—	—	—	—	2	—	—	2	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6
Corn, sweet	—	—	2	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	3	—	—	9
Cucumber	—	—	1	—	—	—	—	—	—	4	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
Eggplant	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Garlic	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Horseradish	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Lettuce	—	—	1	—	—	1	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Melons	—	—	—	—	—	—	—	—	2	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	7
Mushroom	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Onion	—	—	1	—	—	1	—	—	2	7	—	—	—	—	—	—	—	—	—	—	2	1	—	—	—	1	—	—	—	—	2	—	—	—	—	—	17
Peas	—	—	1	—	1	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	7
Pepper	—	—	—	—	—	—	—	—	1	5	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
Popcorn	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Potato, sweet	—	—	2	—	—	—	—	—	1	3	—	—	—	—	—	—	2	2	2	—	3	—	—	1	—	—	—	—	—	—	2	—	1	1	—	—	20
Potato, white	—	—	5	—	3	4	—	—	7	7	1	3	—	—	—	—	2	1	2	3	6	—	2	4	—	1	2	—	3	—	5	—	—	3	—	—	62
Rhubarb	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Soybean	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Spinach	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Squash	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	4
Tomato	—	—	5	—	1	—	—	—	2	12	—	—	—	—	—	—	1	1	3	1	2	—	—	3	—	—	—	—	—	—	1	—	—	3	—	—	35
Flowers*	1	—	8	—	1	1	—	2	2	3	3	4	—	—	—	—	1	—	5	—	7	—	—	—	—	—	2	—	1	2	2	—	—	3	1	1	50
Azalea	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Carnation	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	3
Chrysanthemum	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	3
Gardenia	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	6
Gladiolus	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	3
Lily	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Orchid	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Rose	—	—	2	—	—	—	—	—	2	—	—	1	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	10
Saintpaulia	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Snapdragon	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Stock	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Sweet pea	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Tulip	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Zinnia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
Ornamentals*	1	1	8	—	—	1	—	1	4	5	—	1	—	—	—	—	2	—	1	—	5	—	16	—	2	—	—	—	1	—	1	2	4	11	1	3	71
Christmas tree	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Ericacea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Iris	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Holly, English	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Oaks	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Poinsettia	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1(Rubber Content)					2
Pyrus sp	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Rose	—	—	2	1	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	2	—	—	10
Syringa	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Medicinal plants	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Wildlife	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Antibiotics	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Landscape	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Lawns	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	2
Total	8	2	140	9	30	36	2	12	79	159	22	31	2	1	7	6	19	22	64	32	99	32	35	25	28	9	15	4	55	3	61	10	7	129	11	17	

*General groups include only those not named in project titles; named kinds are not duplicated therein.

are organized primarily around crops rather than around subject matter specialties as is the case in most State institutions. The only research work dealing specificially with the production of these crops which we do not cover is the entomological work.

"I would estimate that the work of the Division as a whole could be divided about as follows:

1. Production investigations, including variety testing, soil management, irrigation, fertilization and related activities .. 25 per cent
2. Breeding for disease resistance, improved horticultural quality, adaptability, etc. .... 35 per cent
3. Disease investigations concerned primarily with determining the cause and developing control measures ...... 20 per cent
4. Transportation and storage including the market diseases and their control, packaging, effect of temperatures, gas treatments, and related studies .... 20 per cent

"Research is carried on in all of the 10 subjects listed under B. [See below.] Once a man is on our staff we make no distinction as to whether he is a horticulturist, a geneticist, a physiologist, or a pathologist. They work as a unit on the problems. Genetics and breeding work may be done by a man whose primary training was in plant pathology, in genetics or in horticulture. The same statement applies to the various other types of problems listed."

The foregoing discussion indicates the present extent of the research phase of American horticultural science. A section of the questionnaire on which this report is based has yielded additional information on this phase: is research carried on by horticulturists on the following subjects, in relation to horticultural crops? Out of 55 departments represented in the replies, the numbers giving affirmative replies to the inquiry concerning each subject are these: (a) soil management: 38, with one additional department co-operating with the Soils department; (b) genetics and breeding: 42, with one additional co-operating with the U. S. Department of Agriculture; (c) control of insects and diseases: 16, with 10 co-operating with entomologists and pathologists, or dealing with breeding for resistance only; (d) handling and storage: 32; (e) processing: 27, with one co-operating with Engineering; (f) marketing: 13, with five co-operating with Economics; (g) physiology: 32, with two co-operating with Plant Physiology departments; (h) plant nutrition, 38: with two co-operating with Plant Physiology or Biochemistry; (i) market grades and quality: 18, with two co-operating with Economics; (j) nutritive values or qualities: 26, with eight co-operating with Home Economics or Chemistry.

To summarize briefly, the majority of departments may carry on research independently on all phases of horticultural art or science except insect and disease control, market grades and quality, and marketing, and on these four phases, one-third or more participate in research.

Reasons given why certain departments of horticultue do not conduct research on certain subjects were: organization of departments:

34; insufficient number of staff members: 22; insufficient training of staff members: 9.

Apparently no marked trend exists at present in horticultural research, with respect to fundamental vs. practical studies, as previously defined: 10 replied that the trend in their respective institutions was toward fundamental, 10 toward practical, and 13 no trend. Seven replied that the trend was toward the use of more fundamental methods in the solution of practical problems, which might be interpreted to mean that horticultural research methods are improving or are less frequently empirical.

Training of Horticultural Scientists

Replies from departments of horticulture in state colleges, universities, and experiment stations apply to 591 staff members. Among these, the following numbers have had graduate training, at least to the extent of a minor, in the respective basic sciences: genetics and cytogenetics, 107; chemistry and biochemistry, 181; soil technology, 69; plant physiology, 192; plant pathology, 101; entomology, 23; plant anatomy, 12; plant morphology, 11; bacteriology, 15; taxonomy, 5; cytology, 4; botany, 5; physics, 2; meteorology, 2; ecology, 2; mathematics, 3. Three have had graduate minors in engineering, refrigerating engineering, and chemical engineering, and 2 in silviculture, which are in themselves technologies, as is horticulture.

Training of research workers on horticultural crops in the United States Department of Agriculture is described in the letter of Dr. J. E. Magness previously cited, as follows:

"Practically all of our professional staff members have had graduate training with either the Master's or the Ph. D. degree. In considering a man for a position as horticulturist we are as much interested in the training he has had in chemistry, soils, plant physiology and genetics as we are in the training he has had in the strictly horticultural field. We are not concerned as to whether he obtained this training in a horticultural department or in other departments of a university but we want to be very certain that he has had the training. Thus we would feel that a man to carry a breeding project would be of little value if he were not well grounded in genetics. Since much of our breeding is for disease resistance, we also expect him to have a working knowledge of plant pathology. A man doing research in fruit production without a working knowledge of soil science would be of limited value. A good working knowledge of plant physiology is essential to practically all phases of our work.

"Our staff at the present time has 186 full time professional workers. These have the following designated titles:

3 chemists and 8 biochemists, 3 botanists, 13 geneticists, 65 horticulturists, 52 plant pathologists, 34 plant physiologists, 1 refrigeration engineer, 2 silviculturists, 5 soil technologists."

Resident Instruction in Horticulture

It is noteworthy that the divisions of the subject matter of horticultural instruction which were set up in the questionnaire evidently were

convenient to practically all departments which replied. Only three undergraduate subjects, spray materials, farm forestry, and beekeeping did not conform to the outline; though enology is listed separately, it properly maý be classified under horticultural processing.

Most of the departments represented in this survey offer either elementary or advanced courses, or both, in general horticulture, fruit growing, and vegetable growing, as shown in Table II. Because not

TABLE II—COURSES OF INSTRUCTION IN HORTICULTURE

Subject or Phase	Elementary		Advanced		Graduate		No. of Departments Offering Courses	Total Number of Courses
	Departments Offering	Number of Courses	Departments Offering	Number of Courses	Departments Offering	Number of Courses		
General horticulture	34	51	11	32	12	38	36	121
Fruit growing	29	46	34	97	22	48	37	191
Vegetable growing	33	50	31	73	22	37	37	159
Floriculture	21	41	20	68	5	9	31	118
Nursery industry	17	18	10	10	4	5	23	33
Plant materials	20	27	14	22	—	—	33	49
Landscape appreciation	19	22	9	13	3	4	25	39
Landscape design	25	34	19	78	6	9	31	121
Plant breeding	6	6	21	26	13	15	13	47
Cytogenetics	—	—	1	1	—	—	1	1
Marketing	8	9	8	9	2	2	15	20
Processing	9	12	11	24	1	1	13	37
Potatoes	4	4	4	4	1	1	7	9
Forcing	—	—	3	3	—	—	3	3
Canning crops	1	1	4	4	—	—	4	5
Citrus	1	1	1	2	—	—	2	3
Bulbs	—	—	1	1	—	—	1	1
Pecans	1	1	—	—	—	—	1	1
Bush and vine fruits	2	2	—	—	—	—	2	2
Spray materials, spraying	1	1	—	—	1	1	2	2
Beekeeping	1	1	—	—	—	—	1	1
Farm forestry	1	1	—	—	—	—	1	1
Enology	1	2	1	2	1	1	1	5
Plant pathology	1	2	1	2	1	4	1	8
Plant regulators	—	—	—	—	1	1	1	1
Nutrient culture	—	—	—	—	1	1	1	1
Methods of research in horticulture	—	—	—	—	1	1	1	1

all departments offering courses in any particular phase present both elementary and advanced courses, but may offer one or the other, the number of departments offering instruction in any of the major phases listed is greater than that shown in either elementary, advanced, or graduate lists. It may be stated that practically all departments which carry on a program of resident instruction offer at least one course in fruit growing, vegetable growing, and general horticulture, and most of them offer one or more courses in floriculture, and either landscape appreciation or landscape design.

Only in general horticulture, nursery industry, plant materials, and landscape appreciation are more elementary courses offered than advanced courses. This indicates that many advanced horticulture courses are given with prerequisities in other phases of horticulture or other fields of study, rather than in the given phase of horticulture, and information not presented in the table but included in returned questionnaires confirms this conclusion.

Only a few departments offer courses on single crops or groups of crops within the commonly classified major plant material divisions, namely fruits, vegetables, flowers, and other ornamental plants. Most departments afford opportunity for practice in elementary courses; 35 replied yes to this question, while six stated that opportunity for practice is limited; none permitted no practice at all.

According to most replies received, courses offered by horticulturists do not duplicate subject matter presented by related departments whose courses may be required of horticulture major students, often as prerequisities for advanced horticulture courses. Many stated that applications of principles or practices learned in other departments, such as soil technology, biochemistry, botany, plant pathology, entomology, genetics, and marketing, are emphasized in horticulture courses. Some departments, on the other hand, frankly admit that duplication or repetition of subject matter occurs, but claim that such repetition may be desirable. Most duplication occurs in soils, fertilizers, plant pathology, and entomology. Among 38 departments answering this question, 13 stated that duplication occurs, 17 that it does not, and 10 stated that subject matter was repeated to the extent necessary for making applications of principles already learned in other departments.

It may not be out of order to describe revisions made recently in horticulture courses at The Pennsylvania State College. Instructors had experienced difficulties in presenting elementary courses, particularly in pomology, floriculture, and olericulture, because these courses were required not only of horticulture major students, but also of agricultural education and agricultural economics majors, and were elective for practically all agricultural majors. While horticulture majors were required to schedule courses in soils, fertilizers, crop diseases, and insect control, other students in the courses frequently had no instruction in these related fields; in consequence, repetition of subject matter was unavoidable for horticulture majors.

To overcome this difficulty, horticulture majors no longer are required to take these elementary courses, but take instead new courses, each of which covers the taxonomy, ecology, and morphology of the important crops in each major group, fruits, vegetables, flowers, and woody ornamentals. Practice formerly provided for (inadequately) in elementary courses is now required in a separate course of one full semester in college orchards, gardens, or greenhouses, under supervision, but with the same pay as that offered to common labor, of all students who have not had experience equivalent to a full season in an approved commercial horticultural establishment specializing in the field of major interest of the student.

Short Courses

Refresher, vocational, or other seasonal short courses are offered by 26 departments, while 17 departments present no short courses. These courses generally are confined to particular groups of crops or to the interests of special groups of commercial horticulturists. Fruits, vegetables, canning crops, nursery practice, fruit or vegetable pest

control, and florists' crops are representative groups of crops or practices, each of which is named as the subject of short or vocational courses, lasting from one or two days to two years; refresher courses of a week or more are presented for vocational school teachers, fertilizer or insecticide and fungicide salesmen, county agents, canners' field men, or freezer locker operators.

Extension Instruction

Extension instruction in horticulture is carried on mainly by specialists who are engaged wholly in this division of instruction: the departments replying reported 100 staff members occupied full-time in extension, 30 part-time each in extension and in resident instruction, and 34 part-time each in extension and in research. Most departments explained that part-time workers in extension and either research or resident instruction either spent most of their time in extension, participating to a very limited extent in resident instruction or research, or were resident instruction or research workers who helped out occasionally in extension. Only in a few departments are both extension work and research or resident instruction major interests of individual staff members.

In only one department do extension workers participate in fundamental research studies; other extension workers who carry on some research engage in practical tests only. In some states, research of the latter type is considered as extension work, and tests are called demonstrations.

Extension workers in horticulture specialize in particular major crops or groups of crops, while those in related departments specialize in phases of work, such as pathology, soils, insect control, or marketing. Thirty-three departments reported specialization among horticulture extension workers on the basis of crop groups, and 27 reported that those in related departments specialized on the basis of phases of work. Horticulture extension specialists usually are responsible for instruction or recommendations on all phases of production, handling, and distribution of their respective groups of crops; specialists in related fields advise them in matters pertaining to the respective phases of work represented by the related department. Most extension specialists in horticulture are quartered with resident instructors and research workers in the office area assigned to horticulture, and most of them are assigned to the department; others are assigned to a department of extension.

Division of Horticultural Duties

The 591 staff members included in the survey are assigned to duties as follows: full-time research, 152; full-time resident instruction, 53; full-time extension instruction, 100; part-time research and resident instruction, 222; part-time research and extension instruction, 34; part-time extension and resident instruction, 30. The most common division of labor is between research and resident instruction, and it is unlikely that this circumstance is accidental. The opinion was vol-

unteered by several co-operators in this study, and probably would have been supported by many others if the question had been asked, that some research study is required to keep a teacher alive. Whether this opinion is expressed or not, the fact that more than four times as many teachers are active in research as are limited to teaching only is in itself a significant commentary.

Horticultural Science: What and Whither?

If we define horticultural science in terms of the best usage today, of which it is hoped that this survey provides a measure, our definition will read about as follows: Horticultural science is the application of the methods of any convenient discipline to the solution of problems and the accumulation of knowledge of the selection, propagation, culture, improvement, protection, distribution, utilization and appreciation of plants traditionally associated with the garden or home grounds and of their products. It is an applied science, and is sufficiently self-contained, distinct, and well established to be dissociated from the sciences which are its forebears, and recognized for the organic entity which it has come to be.

The basis of differentiation of our technology from its contributing basic sciences is our interest in a traditionally unified group of plants; this interest compels us, whatever are the disciplines that our training has placed at our disposal, to call ourselves by one name. Whether one be taxonomist, physiologist, soil technologist, pathologist, entomologist, chemist, physicist, geneticist, or economist, if his ultimate interest is in these groups of plants as economic or esthetic objects, he becomes a horticulturist, and is proud to be so designated and associated.

The form which horticultural science will assume in the time to come is not wholly a matter of conjecture; it may be estimated from the differentiation which has taken place in those states in which the horticultural industry has been established for some time as a major agricultural enterprise. In these states, major crop groups form the basis for further departmentalization. This is a natural development. It is fully proper that horticulture shall give rise to new technologies and shall be content to recognize them as its own progeny, provided that they are self reliant, and appropriate to themselves the means of their own advancement.

Horticulture will be weakened and may disappear if the contributing sciences are permitted to appropriate its parts to themselves. Such a development is to be avoided, not only for the sake of horticulture, but also for the sake of the sciences which nourish it, because they too would not profit thereby. We are justified in being confident that horticultural science will continue to advance; as other sciences advance, their contributions to horticulture will be realized, to the advantage and mutual advancement of both.

Register of New Fruit and Nut Varieties List No. 2

By Reid M. Brooks and H. P. Olmo, *University of California, Davis, Calif.*

The cordial reception which these summaries have found among horticulturists, together with the cooperation received from all parts of the country, now warrants the publication of annual lists, in which current introductions of varieties will become more and more important. It is time to acknowledge the help of our colleagues in supplying and checking much of the information contained in the Register. We hope that each state will find it profitable and desirable to have one or more interested horticulturists serve as contributors to this project.

Although every effort is made to check all data by submitting them to competent authorities before publication, errors and omissions will continue to occur. It therefore seems appropriate to note, at the beginning of each list, any corrections of previous work that have been called to our attention. This policy is used herewith.

Obviously, the descriptive data should be as uniform as possible; but a standard blank for each fruit has not yet materialized. To formulate such a blank would be a worthwhile endeavor for those specializing in the various fruits; and advances are now being made in this field. Until better methods of description are available, we shall have to content ourselves with relative terms.

REVISIONS, LIST NO. 1[1]

Peach

Babcock.—Originated in Berkeley, California, by E. B. Babcock and C. O. Smith. Selected in 1923 at the California Citrus Experiment Station (H. B. Frost and J. W. Lesley), and introduced commercially by George P. Weldon, Ontario, California.

Fertile Hale.—Origin unknown.

Strawberry

Tennessee Shipper.—Patent no. 570.

LIST NO. 2

Apple

Alton.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Early McIntosh x New York 845 (Red Canada x Yellow Transparent); cross made in 1923, first full crop in 1935. Fruit: similar to Crimson Beauty; flavor mild, subacid; ripens just after Crimson Beauty; eating and cooking apple, for home and roadside markets. Tree: most nearly resembles Crimson Beauty.

Astrachan No. 2391.—See **Carlton.**

Baxters Black Winesap.—Originated in Nauvoo, Illinois, by Frederick K. Baxter, Emil O. Baxter, and Cecil J. Baxter, Jr. Introduced commercially in 1944. Patent no. 619. Parentage unknown; selected in 1930. Fruit: size large; color deep red approaching black; ripens 10 days later than Winesap; holds well on tree; excellent keeper in common storage. Tree: rapid grower; very hardy; early bearer.

[1]*Proc. Amer. Soc. Hort. Sci.* 45: 467–490. 1944.

Beverly Hills.—Originated in Berkeley, California, by the University of California (W. H. Chandler) and fruited at Los Angeles, California, as seedling no. 302. Introduced commercially in 1945. Melba x Early McIntosh; seed planted in 1939; first fruited in 1942. Fruit: flesh white; skin pale yellow with red stripes and splashed with red; quality very good; most nearly resembles McIntosh. Tree: moderately well suited to southern California coastal climate.

Carlton *(Astrachan No. 2391)*.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Montgomery x Red Astrachan; cross made in 1912. Fruit: ripens 1 month later than Red Astrachan; large, round-conic; skin attractive dark red; flesh white, tender, juicy, subacid, of Astrachan flavor; home use and roadside markets. Tree: vigorous; annual bearer.

Close *(USDA 57)*.—Originated in Arlington, Virginia, by the United States Department of Agriculture (C. P. Close). Introduced commercially in 1938. Parentage uncertain; selected about 1925. Fruit: ripens with or slightly ahead of Yellow Transparent; fairly large, diameter 2½ inches or more; quality fairly good for both dessert and cooking; stands high summer temperatures well; promising as an early red apple for both home and commercial purposes. Tree: widely adapted.

Cortland.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced for trial in 1915. Ben Davis x McIntosh; cross made in 1898, seed germinated in 1899. Fruit: attractive red, darkly and obscurely striped; bloom heavy; large; flesh white, slow to discolor on exposure to air; hangs well on tree; stands handling well; dessert, cooking, market; most nearly resembles McIntosh. Tree: early and annual bearer; very hardy. Has become an important commercial variety.

Dunning.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Early McIntosh x Cox Orange; cross made in 1923; first full crop in 1934. Fruit: skin red striped; medium-sized; flesh sweet, excellent quality; very early ripening (early August); for local use and roadside markets.

Early McIntosh.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Yellow Transparent x McIntosh; seed borne in 1909; fruit first described in 1918. Fruit: ripens in early August; flavor excellent; most nearly resembles McIntosh.

Greendale.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. McIntosh x Lodi; cross made in 1924; first full crop in 1935. Fruit: skin attractive green; well shaped; flavor mild; quality good; for desert and cooking purposes; extends season of Lodi for local and roadside markets; most nearly resembles McIntosh in shape and Lodi in color.

Kendall.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1932. McIntosh x Zusoff; cross made in 1912. Fruit: skin handsome dark red color; large; whitish, fine-grained flesh of McIntosh; flavor sprightly; season about that of McIntosh, but keeps longer; hangs well on tree.

Lodi.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1924. Montgomery x Yellow Transparent; cross made in 1911. Fruit: does not grow mealy and soften at center as quickly as Yellow Transparent; larger, keeps longer, ripens later than Yellow Transparent; culinary and fresh use; most nearly resembles Yellow Transparent.

Macoun.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. McIntosh x Jersey Black; seed borne in 1909; fruit first described in 1918. Fruit: similar to McIntosh, but smaller; red-skinned; white-fleshed; richly flavored, aromatic; ripens 1 month later than McIntosh.

Medina.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1922. Deacon Jones x Delicious; cross made in 1911. Fruit: larger, better

colored, more attractive than Delicious because of golden-yellow ground color; prolongs season of Delicious, which it most nearly resembles.

Melrose.—Originated in Wooster, Ohio, by the Ohio Agricultural Experiment Station (Freeman S. Howlett). Introduced commercially in 1944. Jonathan x Delicious; selected in 1937. Fruit: quality better than Rome Beauty; does not develop Jonathan spot; harvesting season 7 to 10 days later than Jonathan; storage season through March into April; resembles Jonathan in color and shape, but less tart. A good late apple to supplement Stayman Winesap and Rome Beauty in regions of long growing season, and in areas where the parents are grown.

Milton.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Yellow Transparent x McIntosh; cross made in 1909. Fruit: color attractive; characteristic McIntosh taste and aroma; sometimes has unattractive bulge on one side; season after Early McIntosh and preceding McIntosh by a month or 6 weeks; most nearly resembles McIntosh.

Newfane.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1927. Deacon Jones x Delicious; seed borne in 1911 and germinated in 1912. Fruit: large, oblong-conic; attractive red; flesh tender, medium juicy, mildly flavored with a pronounced Delicious aroma; dessert apple; ripens with Delicious, which it most nearly resembles.

Ogden.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1928. Zusoff x McIntosh; cross made in 1912; first full crop in 1924. Fruit: dark red with heavy bloom, similar to McIntosh but with considerable scarfskin; flesh white, often stained, aromatic, sweet; season little earlier than McIntosh; good baking apple; most nearly resembles McIntosh.

Orleans.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1924. Deacon Jones x Delicious; cross made in 1911. Fruit: more attractive and larger than Delicious; keeps in common storage 6 weeks longer than Delicious; similar to Medina but keeps longer; of the Delicious type. Tree: similar to Medina and thrives in some soils to which Medina is not adapted.

Redfield.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Wolf River x *Malus niedzwetzkyana*; cross made in 1924; first full crop in 1935. Fruit: skin dark solid red; flesh deep red. Tree: foliage dark with reddish-green tinge early in season; large, dark pink flowers. An ornamental variety; most nearly resembles *M. niedzwetzkyana*, but larger.

Redford.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Wolf River x *Malus niedzwetzkyana;* cross made in 1924. Tree: sister seedling of Redfield which it closely resembles, except the flowers are lighter in color, being deep pink. Most nearly resembles *M. niedzwetzkyana*. An ornamental variety.

Red Graham.—Originated in Manistee, Michigan, by the Manistee Orchard Company. Introduced commercially in 1936. Patent no. 278. Bud mutation of Northern Spy; discovered in 1926. Fruit: large, shaped like Northern Spy; color brighter than parent; ripens with McIntosh; keeps in cold storage until spring; good pie and general purpose apple. Tree: growth is similar to Northern Spy.

Redhook.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. McIntosh x Carlton; cross made in 1923; first full crop in 1935. Fruit: skin very attractive dark red with heavy bloom; flesh white but sometimes reddish, highly aromatic; season between Milton and McIntosh; dessert apple for home and roadside markets.

Red Sauce.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1926. Deacon Jones x Wealthy; cross made in 1910; first full crop in 1917.

Fruit: skin nearly solid red; roundish conic, large; flesh coarse, briskly subacid, often red to coreline; makes a red sauce when cooked; season October.

Red Spy.—Originated about 1895 in Victor, New York, by Wm. S. Greene. Introduced for trial in 1923. Bud mutation of Northern Spy; sent to the New York State Agricultural Experiment Station in 1910 by C. E. Greene (son of Wm. S. Greene). Fruit: skin solid bright red, otherwise typical of parent.

Red Striped Graham.—Originated in Manistee, Michigan, by the Manistee Orchard Company. Introduced commercially in 1936. Patent no. 293. Bud mutation of Northern Spy; discovered in 1926. Fruit: large and shaped like Northern Spy; color brighter than parent but striped; ripens with McIntosh; keeps well in cold storage until spring; good pie and general purpose apple. Tree: growth similar to Northern Spy.

Sweet Delicious.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1922. Deacon Jones x Delicious; cross made in 1911. Fruit: large; color attractive; sweet aromatic flavor of Delicious; home use for dessert and baking; season a little later than Sweet McIntosh. Resembles Delicious in shape, but lipping of stem and dull grayish scarf-skin over surface are like Deacon Jones.

Sweet McIntosh.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1922. Lawver x McIntosh; cross made in 1909. Fruit: externally resembles Lawver, but sweet flavor suggests McIntosh; home use (baking and fresh).

USDA 57.—See **Close.**

Webster.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. New York 26 (Ben Davis x Jonathan) x New York 19 (Ben Davis x Jonathan); cross made in 1912; first full crop in 1921. Fruit: large; skin solid bright red; season late and keeps well into spring; a cooking apple; quality not high enough for dessert variety; most nearly resembles Jonathan in shape, but much larger. A triploid variety.

Apricot

Doty.—Originated on the farm of Floyd Doty, Oaks Corners, New York; tree was on the farm before Mr. Doty purchased it. Introduced for trial in 1944. Parentage unknown. Fruit: medium-sized; skin attractive light golden yellow with few reddish markings; flesh sweet, nearly free from fiber; home and local market. Tree: large; hardy.

Earligold.—Originated in Ontario, California, by W. H. Kemple. Introduced commercially in January, 1938. Parentage unknown; selected in 1928. Fruit: resembles Royal; usually matures about 2 weeks ahead of Newcastle in southern California. Tree: resistant to delayed foliation.

Henderson.—Originated in Geneva, New York, by George W. Henderson. Introduced for trial in 1935. Parentage unknown. Fruit: large; roundish; flesh yellow, slightly fibrous, sweet; quality good; freestone. Tree: strong; vigorous.

Avocado

Darwin.—Originated in Santa Ana, California, by Mr. Darwin Speck. Introduced commercially in 1946. Parentage unknown; discovered in November, 1941. Fruit: skin black; flavor fair; 6 to 8 ounces; oil content 20.1 per cent; of Mexican type. Tree: hardy; productive.

Gano.—Originated in Whittier, California, by Jennie C. Gano. Introduced commercially in 1935. Patent no. 100. Open-pollinated seedling of Colorado; selected in 1918. Fruit: rather long, dull green; skin tough; averages 1 pound; little fiber; flavor excellent; oil content about 20 per cent; season July and August. Tree: vigorous, upright; stands frost slightly better than most Guatemalans.

Graham.—Originated in La Habra, California, by M. M. Graham. Introduced commercially in December, 1945. Patent no. 662. Open-pollinated seedling of Lyon; selected in 1944. Fruit: oil content high; flavor excellent; cut

surface of fruit seals over and can be kept for several days at room temperature. Tree: more easily propagated than Lyon; slender; suitable for home planting; upright growing.

Hellen.—Originated in Santa Monica, California, by Mrs. S. L. Duey. Introduced commercially in December, 1941. Parentage unknown. Fruit: dark green; pyriform; 9.5 ounces; seed tight; oil content 21 per cent; season June to September.

Henry Select.—See **Henry's Select.**

Henry's Select *(Henry Select)*.—Originated in Escondido, California, by Jesse L. Jones and Charles C. Henry. Introduced commercially in 1937. Patent no. 234. Parentage unknown; discovered in 1931. Fruit: deep maroon-purple; skin smooth and glossy; 9 ounces; season September to November at Escondido; oil content 18 per cent; seed small, conical, loose when mature. Tree: does not bear well nor consistently.

Itzamna *(P. I. 43486; P. I. 55736)*.—Originated in Santa Maria de Jesus, Guatemala, and introduced by the United States Department of Agriculture (F. W. Popenoe) in 1916. Introduced commercially in 1923. Parentage unknown; of Guatemalan race. Fruit: light green; coarse; pyriform; 12 to 18 ounces; skin thick; seed small; oil content 15 per cent; quality excellent; season September to December in southern California, February 15 to April 15 in Florida; storage quality sometimes poor.

Major.—Originated in Katz Grove, Florida, by Herbert Katz. Introduced commercially in 1942. Parentage unknown; selected in 1942. Fruit: attractive, good quality; season October and November.

Marfield.—Originated in Marfield Grove, Florida, by H. A. Marsh. Introduced commercially in 1943. Parentage unknown; selected in 1940. Fruit: season July.

Mary Martin.—Originated in San Diego, California, by John Martin Reinecke. Introduced commercially in January, 1943. Patent no. 576. Open-pollinated seedling of Linscott; selected about 1938. Fruit: high quality; medium size; most nearly resembles Nabal. Tree: produces regularly and heavily.

Middleton.—Originated in Pomona, California, by E. E. Middleton. Introduced commercially in 1941. Parentage unknown; of Mexican race; selected about 1932. Fruit: dark purple; pyriform; 8 ounces; oil content about 15 per cent; flavor excellent and of high quality; season just before Fuerte. Tree: tall, slender; some frost resistance.

P. I. 43486.—See **Itzamna.**

P. I. 55736.—See **Itzamna.**

Ryan.—Originated in Whittier, California, by E. L. Ryan. Introduced commercially in 1936. A hybrid between Guatemalan and Mexican races; possibly an open-pollinated seedling of Amigo. Fruit: green; slightly rough; pyriform; 10 to 14 ounces; skin leathery; seed large; quality fair to good; oil content 20 to 25 per cent; season May to September. Tree: vigorous; propagates readily.

Tomko.—Originated in Carlsbad, California, by Sam Thompson. Introduced commercially in 1944. Patent no. 628. Parentage unknown (but probably a seedling of Cantel x Fuerte). Fruit: ripens after Fuerte; 10 or 11 ounces; green, leathery skin which peels easily; stem offset; oil content 24 per cent.

Zutano.—Originated in Fallbrook, California, by W. L. Truitt. Introduced commercially in 1941. Parentage unknown; of Mexican race; selected in 1926. Fruit: light green; pyriform; 8 to 12 ounces; skin very thin; oil content about 16 per cent; flavor good; season December and January. Tree: consistent producer; more hardy than Fuerte.

Blackberry

Bowen.—Originated in Burlingame, California, by J. C. Bowen. Introduced commercially in 1944. Patent no. 635. From a wild thornless blackberry; discovered in 1940. Fruit: large; matures early; seeds very small. Bush: thornless; does not sucker or propagate from root cuttings; quite productive. The variety may be identical with Cory Thornless.

John Innes.—Originated in Merton Park, London, England, by the John Innes Institute (M. B. Crane). Introduced commercially in the United States in January, 1944. *Rubus rusticanus* x *R. thyrsiger;* selected about 1926 or 1927. Fruit: very firm; sweet; late ripening; might be valuable for home use as a late-ripening variety. Most nearly resembles Oregon Evergreen blackberry.

Lowden.—Originated in Hamilton, Ontario, Canada, by Edward Lowden. Introduced commercially in 1939. Possibly a mutation of Snyder; discovered about 1926 or 1927. Fruit: core small; colors uniformly. Bush; hardy, productive, resistant to orange rust.

Blueberry

Cabot.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1920. Brooks x Chatsworth. Fruit: early; season long.

Catawba.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced as a novelty in 1932. F_2 of (Brooks x Russell). Fruit: Catawba-grape color. Bush: half-high.

Concord.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1928. Brooks x Rubel. Fruit: midseason. Bush: productive.

Dixi.—Originated in Weymouth, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1936. (Jersey x Pioneer) x Stanley. Fruit: very large. Bush: productive.

Greenfield.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1926. Brooks x Russell. Fruit: early. Bush: half-high.

Jersey.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1928. Rubel x Grover. Fruit: late; large; fine blue; good keeper. Bush: easily pruned.

June.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1930. (Brooks x Russell) x Rubel. Fruit: early; short season.

Katharine.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1920. Brooks x Sooy. Fruit: flavor pronounced; berry large.

Pioneer.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1920. Brooks x Sooy. Fruit: flavor pronounced; size large; midseason.

Rancocas.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1926. (Brooks x Russell) x Rubel. Fruit: early midseason. Bush: productive; resistant to stunt virus disease and canker.

Redskin.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1932. F_2 of (Brooks x Russell). Fruit: red. Bush: half-high.

Scammell.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1931. (Brooks x Chatsworth) x Rubel. Bush: productive, especially in North Carolina; resistant to canker.

Stanley.—Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1930. Katharine x Rubel. Fruit: midseason; flavor very pronounced. Bush: easy to prune.

Wareham.—Originated in East Wareham, Massachusetts, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1936. Rubel x Harding. Fruit: very late; flavor pronounced.

Weymouth.—Originated in Weymouth, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1936. June x Cabot. Fruit: very early; large. Bush: very productive.

Cherimoya

Ott.—Originated in Guadalajara, Mexico, and fruited at Whittier, California, by Wm. H. Ott. Introduced commercially in 1946. Patent no. 656. An open-pollinated seedling of unknown parentage. Fruit: flavor very pronounced and distinct; high sugar content; skin tough but thin. Tree: fairly self-fruitful. A prospective shipping variety.

Cherry

Gil Peck.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1936. Napoleon x Giant; cross made in 1925; first full crop in 1933. Fruit: skin dark purplish-black; large; firm-fleshed; rich flavor; cracks less than Napoleon; season between Noble and Geant d'Hedelfingen; most nearly resembles Giant.

Late Lambert.—Originated in Charlevoix, Michigan, by C. Fairman. Introduced commercially in 1944. Patent no. 627. Bud mutation of Lambert; discovered in 1933. Fruit: ripens 10 to 14 days after Lambert, which it most nearly resembles.

Noble *(St. Margaret, Tradescant Heart)*.—An old English variety of unknown origin. Introduced for trial in the United States in 1943 by the New York State Agricultural Experiment Station. Parentage unknown. Fruit: sweet; flesh firm; color dark purplish red; cracks less than most late varieties; season between Schmidt and Geant d'Hedelfingen; heart-shaped.

St. Margaret.—See **Noble.**

Seneca.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1924. Early Purple Guigne x unknown; cross made in 1911; first full crop in 1922. Fruit: sweet; early, ripening 2 weeks earlier than Black Tartarian; large, round-cordate; skin purple-black; flesh soft, juicy, melting, rich flavor; pit free; skin does not crack. Tree: vigorous; productive; most nearly resembles Black Tartarian.

Sodus.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Napoleon x Giant; cross made in 1925; first full crop in 1935. Fruit: sweet; skin light-colored; resistant to cracking; large; firm-fleshed; ripens between Emperor Francis and Napoleon; most nearly resembles Victor.

Tradescant Heart.—See **Noble.**

Chestnut

Carr *(Carrissima)*.—Originated in Magnolia, North Carolina. Introduced commercially in 1935. Parentage unknown; grown from seed *(Castanea molissima)* procured from Tientsin, China, and the small tree sent to R. D. Carr by the United States Department of Agriculture in 1915; selected in 1930; first grafted in 1932 by H. F. Stoke of Roanoke, Virginia. Nut: size good; very sweet; too gray to be as attractive as some others; quality excellent.

Carrissima.—See **Carr.**

Hobson.—Originated from seed procured by the United States Department of Agriculture northwest of Peking, China, and sent to Jas. Hobson, Jasper, Georgia, as a small seedling in 1917. First grafted in 1932 by H. F. Stoke, Roanoke, Virginia, although named in 1930. Introduced commercially in 1935. Parentage unknown. Fruit: smaller than Carr; more attractive in appearance than Carr, but no sweeter. Tree: thought by some to be more prolific than Carr.

Crab Apple

Humboldt.—Originated in Ettersburg, California, by Albert Etter. Introduced commercially in 1944. Patent no. 658. Open-pollinated seedling of Transcendent which it resembles. Combines quality of fruit with very large flowers of exceptional beauty.

Cranberry

Stankavich.—Originated in Bandon, Oregon, by Joseph F. Stankiewicz. Introduced commercially in 1926. Trademarked Original Stankavich. Oregon

Native x an Eastern variety; selected between 1914 and 1917. Fruit: size averaging ¾ to ⅝ inch; global; high color; low acid content, good sugar content; ripens early. Plant: produces well. Most nearly resembles Michigan Bennett.

Elderberry

Adams.—Originated in Union Springs, New York, by William W. Adams. Introduced for trial in 1926. Selections made from wild forms; present variety constitutes two clonal selections. Fruit: clusters and berries exceptionally large. Bush: strong; vigorous; productive.

Fig

Beall.—Originated in Santa Clara Valley, California, by W. A. Beall. Introduced commercially in 1924. Parentage unknown; seedling transplanted to Fresno, California, and first fruited there about 1922. Fruit: purplish black with amber pulp; excellent in Imperial Valley, San Diego County, and Fresno. Tree: produces two crops for fresh fruit purposes.

Kearney *(USDA Rixford 2830)*.—Originated in Kearney Park, Fresno, California, by the United States Department of Agriculture (G. P. Rixford). Introduced commercially in 1925. Parentage unknown; selected in 1925. Fruit: skin green; pulp violet-purple; size above medium to large. Tree: abundant cropper; caprifig.

USDA Rixford 2830.—See **Kearney.**

Filbert

Brag.—Originated in Westbank, British Columbia, Canada, by J. U. Gellatly. Introduced commercially in 1928. F_2 open-pollinated seedling of Kentish Cob; selected in 1926. Nut: large, free-husking, clean kernels; 3 to 4 nuts per cluster; cracks easier than Craig, which it most nearly resembles.

Comet.—Originated in Westbank, British Columbia, Canada, by J. U. Gellatly. Introduced commercially in 1928. Seedling of unknown parentage. Nut: very attractive; long; shell thin; kernel clean, smooth, plump. Tree: produces good crops if cross-pollinated.

Craig.—Originated in Westbank, British Columbia, Canada, by J. U. Gellatly. Introduced commercially in 1928. F_2 open-pollinated seedling of Kentish Cob; selected in 1926. Nut: large, oval; medium shell; large kernel. Tree: produces good crops if cross-pollinated.

G 2.—See **Holder.**

Holder *(G 2)*.—Originated in Westbank, British Columbia, Canada, by J. U. Gellatly. Introduced commercially in 1928. F_2 open-pollinated seedling of Kentish Cob; selected in 1926. Nut: high quality; shell thin; kernel 50 to 53 per cent of dried nut, smooth, high oil content. Tree: late-blossoming.

Gooseberry

Fredonia.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1927. Open-pollinated seedling of unknown English-type gooseberry; originated in 1910. Fruit: very large; skin dark red; of the English type; ripens late; quality good; appearance attractive; keeps and ships well.

Grape

Almission.—Originated in Fresno, California, by L. O. Bonnet. Introduced commercially in 1941. Mission x Alicante Bouschet; selected about 1936. Fruit: black; cluster loose, large; juice red. Vine: vigorous. A wine grape variety.

Bonnet Seedless.—Originated in Fresno, California, by L. O. Bonnet. Introduced commercially in 1934. Patent no. 88. Muscat of Alexandria x Thompson Seedless; selected in 1932. Fruit: only partially seedless; appears to be much inferior to Thompson Seedless in all characteristics under California conditions. Vine: weak grower, not fruiting uniformly.

Bonnet Seedless Muscat.—Originated in Fresno, California, by L. O. Bonnet. Introduced commercially in 1941. Muscat of Alexandria x Sultana; selected about 1936. Fruit: berry small, variable; cluster medium; seeds partly hardened. Vine: produces irregular crops; weak grower. Now obsolete.

Christmas.—Originated in Santa Rosa, California, by Luther Burbank. First introduced commercially in 1915 by the originator; reintroduced in 1926 by a California nursery. Claimed to be a seedling of Pierce. Fruit: similar to Concord; late; long ripening season. Vine: very vigorous; suitable for arbor planting.

Dunkirk.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced for trial in 1920. Brighton x Jefferson; cross made in 1899. Fruit: larger than Delaware; good shipper; ripens late; clusters uniform, compact, most nearly resembling Delaware. Vine: vigorous; hardy; healthy; productive; very short internodes; may have value for wine.

Fredonia.—Originated in Fredonia, New York, by the New York State Agricultural Experiment Station (F. E. Gladwin). Introduced for trial in 1927. Champion x Lucile; cross made in 1915. Fruit: 2 weeks earlier than Worden; clusters medium, cylindrical, compact; berries large; skin thick and tough; quality good, superior to any other black variety of its season. Vine: susceptible to downy mildew.

Golden Muscat.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (R. D. Anthony). Introduced for trial in 1927. Muscat Hamburg x Diamond; cross made in 1915. Fruit: berry large, oval, juicy, tender, sweet, aromatic; ripens 2 weeks later than Concord; for home use; clusters large, tapering, compact; most nearly resembles Diamond in golden color; some aroma of European Muscat. Vine: vigorous; productive.

Keuka.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1924. Chasselas rose x Mills; cross made in 1913; seed germinated in 1914; first fruited in 1919. Fruit: dark red with heavy bloom; cluster and berry medium sized; cluster compact; flesh crisp and hardly slip-skin; vinifera-type flavor; ripens about 1 week before Catawba; most nearly resembles Delaware in appearance.

Perlette.—Originated in Davis, California, by the California Agricultural Experiment Station (H. P. Olmo). Introduced commercially in 1946. Scolokertek hiralynoje no. 26 x Sultanina marble; cross made in 1936; vine first fruited in 1940. Fruit: seedless; berry white, larger than Thompson Seedless; spherical, crisp, neutral flavor, low in sugar and acidity; cluster large; very early ripening, one month before Thompson Seedless. Vine: vigorous; fruitful when spur pruned; very productive.

Pontiac.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced for trial in 1922. Herbert x Worden; cross made in 1903. Fruit: berries large; skin dark purple; rarely cracks; long-keeping; flavor sweet and vinous; small number of seeds; quality high; good for home use; clusters large and well-formed. Vine: self-sterile. No longer recommended for planting.

Scarlet.—Originated in Davis, California, by the California Agricultural Experiment Station (H. P. Olmo). Introduced commercially in 1946. Golden Muscat x Teinturier; cross made in 1935; first fruited in 1939. Fruit: black; cluster compact; berry medium size; juice abundant, dark red, high sugar and acid, mild Concord-type flavor; resembles Teinturier in color of berry and juice. Vine: resistant to *Oidium;* dormant buds fruitful; foliage blood red in autumn. For home and commercial production of grape juice.

Seneca.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (R. D. Anthony). Introduced for trial in 1930. Lignan blanc x Ontario; seed borne in 1917. Fruit: berry oval, yellow; clusters medium, compact; skin tender. Vine: vigorous, hardy, productive; of vinifera type.

Sheridan.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced for trial in 1921. Herbert x Worden; cross made in 1903. Fruit: black; clusters compact, large; skin tough; stores exceptionally well; matures about 1 week after Concord. Vine: hardy; productive.

Stout Seedless.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (A. B. Stout). Introduced for trial in 1930.

(Triumph x Dutchess) x Sultanina rose; cross made in 1921; first fruited in 1926. Fruit: small; oval; skin greenish yellow; flesh juicy, sweet, vinous; clusters large, medium compact. Vine: fairly hardy but cannot be grown in severe climates. No longer recommended for planting.

GRAPEFRUIT

Henninger's Ruby.—See **Ruby.**

Red Blush.—See **Ruby.**

Ruby *(Ruby Red, Red Blush, Henninger's Ruby).*—Originated in McAllen, Texas, by Albert Henninger. Introduced commercially in 1934 or 1935. Patent no. 53. Bud mutation of Thompson; discovered in 1929. Fruit: red blush on rind; flesh pink; deeper red than Thompson (Marsh Pink).

Ruby Red.—See **Ruby.**

LEMON

Armstrong Seedless.—Originated in Riverside, California, by Sanford Johnson. Introduced commercially in 1939. Patent no. 342. Bud mutation of Eureka. Appears to be more vigorous but less fruitful than parent.

Perrine.—Originated in Eustis, Florida, by the United States Department of Agriculture (Walter T. Swingle). Introduced commercially in 1931. Genoa lemon x Mexican lime; selected in 1909. Fruit: size, shape, and quality of commercial lemon. Tree: resistant to scab and withertip, but highly susceptible to gummosis caused by *Diplodia natalensis.* Variety going out of commercial production.

LIME

Eustis.—Originated in Eustis, Florida, by the United States Department of Agriculture (Walter T. Swingle). Introduced commercially in 1923. Mexican lime *(Citrus aurantifolia)* x round kumquat *(Fortunella japonica)*; selected in 1910. Fruit: fine quality; juicy; smooth, thin rind; hardy. Tree: resistant to withertip; hardy.

Idemor.—Originated in Homestead, Florida, by George L. Polk. Introduced commercially in 1941. Patent no. 444. Bud mutation of Tahiti (Persian) lime *(Citrus aurantifolia)*; selected prior to 1934. Tree: resistant to disease; heavy bearing. Most nearly resembles parental type.

Lakeland.—Originated in Eustis, Florida, by the United States Department of Agriculture (Walter T. Swingle). Introduced commercially in 1923. Mexican lime *(Citrus aurantifolia)* x round kumquat *(Fortunella japonica)*; selected in 1910. Fruit: fine quality; juicy; rind smooth, thin. Tree: resistant to withertip; hardy.

Newell *(Newell's Thornless Key).*—Originated in Orlando, Florida, on the John Buchanan place. Introduced commercially in 1945. Parentage unknown; discovered about 1940. Fruit: seedless; smooth-skinned; flavor like Mexican lime. Tree: stands more frost than Mexican lime; thornless; everbearing; pollen sterile. Most nearly resembles Mexican or "Key" lime.

Newell's Thornless Key.—See **Newell.**

MANDARIN

Silverhill.—Originated in Mary, Florida, by the United States Department of Agriculture (Walter T. Swingle). Introduced commercially in 1931. Seedling of Owari Satsuma x sweet orange pollen, but apparently not a hybrid; selected in 1909. Fruit: large-sized; good quality. Tree: extra vigorous and hardy.

MANGO

Kent.—Originated in Miami, Florida, by Leith D. Kent. Introduced commercially in 1944. Open-pollinated seedling of Brooks; selected in 1938. Fruit: quality excellent; very little fiber; seed small; skin blushed crimson; season later than Haden. Tree: bears well.

Zill.—Originated in Lake Worth, Florida, by Carl King. Introduced commercially in 1940. Probably open-pollinated seedling of Haden; seedling first fruited in 1930. Fruit: quality very good; very little fiber; seed small; skin highly colored, shades of crimson with yellow ground color; ships well. Tree: heavy bearer.

Nectarine

Bim.—Originated in Le Grand, California, by F. W. Anderson. Introduced commercially in 1944. Patent no. 575. F_2 seedling of J. H. Hale peach x Lippiatt; selected in 1934. Fruit: quality good; skin bright red; most nearly resembles Kim.

Garden State.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1934. Patent no. 92. Elberta, open-pollinated; selected in 1922. Fruit: flesh yellow; freestone.

Hayes Late.—Originated in Fresno, California, by Mrs. Signa Larsen Hayes. Introduced commercially in 1944. Patent no. 587. Stanwick x a late peach; selected in 1939. Fruit: flesh white; clingstone; large; aromatic; ripens late; good keeping and shipping quality; cans well because of firmness. Most nearly resembles Quetta.

Violet.—Supposedly originated in Hughson, California, by George Edward Alexander. Introduced commercially in 1937. Patent no. 328. Parentage unknown; discovered in 1929. Fruit: flesh white; freestone; skin color mottled purple, thick, tough, sour, tenacious to flesh, slight tendency to crack; moderately large. Probably identical with P. I. 65979 which was introduced from Italy by the United States Department of Agriculture.

Orange

Armstrong Seedless Valencia.—Originated in Anaheim, California, by Pearl C. Mohn. Introduced commercially in December, 1939. Patent no. 124. Bud mutation of Valencia; discovered about 1928. Fruit: seedless; quality equal to or slightly better than Valencia.

Diller.—Originated in Phoenix, Arizona, by Daniel Diller. Introduced commercially in 1920. Claimed to have originated as a seedling from a shipment of trees purchased in Florida and fruited in Arizona; selected in 1910. Fruit: claimed to have only a few seeds. Tree: fairly frost resistant. The variety resembles Parson Brown.

Dream Navel.—Originated in Seminole County, Florida, by Donald J. Nicholson. Introduced commercially in 1944. Patent no. 625. Parentage unknown; selected in 1939. Fruit: seedless; fine flavor; matures in early October at Orlando, Florida; fine appearance; juice content high. Tree: heavy bearer.

Paradise Navel.—Originated in Lake County, Florida, by Donald J. Nicholson. Introduced commercially in 1944. Patent no. 548. Parentage unknown; discovered in 1934 or 1935. Fruit: seedless; skin very smooth; color attractive. Tree: heavy bearer; vigorous.

Robertson Navel.—Originated in Redlands, California, by Roy Robertson. Introduced commercially in 1936. Patent no. 126. Bud mutation of Washington Navel; discovered in 1925. Fruit: in some areas ripens from 2 to 4 weeks earlier than Washington Navel. Tree: precocious in bearing habit, but somewhat lacking in vigor on sweet and sour orange rootstock.

Summernavel *(Workman Navel)*.—Originated in Riverside, California by J. A. Workman. Introduced commercially in 1942. Patent no. 347. Bud mutation of Washington Navel; discovered about 1934. Fruit: ripens later than parent variety.

Workman Navel.—See **Summernavel.**

Zellwood Satin.—Originated in Zellwood, Orange County, Florida, by K. C. Moore. Introduced commercially in 1945. Parentage unknown. Fruit: skin smooth, satiny, glossy; size small; semi-seedless; very juicy; rich flavor. Tree: vigorous, dense, prolific; most nearly resembles Hamlin.

Orangequat

Nippon.—Originated in Washington, D. C., by the United States Department of Agriculture (Eugene May). Introduced commercially in 1932. Unshiu Satsuma orange *(Citrus reticulata)* x Meiwa kumquat *(Fortunella japonica x F. margarita)*. Fruit: excellent for marmalade; ripens October to February; rind sweet, edible, very attractive. Tree: vigorous, hardy, productive.

Papaya

Betty.—Originated in Miami, Florida, by Bronson Bayliss. Introduced commercially about 1934. Parentage unknown; selected about 1933. Fruit: excellent dessert quality; weight 2 to 3 pounds. Tree: semi-dwarf.

Peach

Afterglow.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1938. J. H. Hale x New Jersey 27116; cross made in 1923. Fruit: flesh yellow; freestone; follows Elberta in ripening time.

Ambergem.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1934. Belle x self; seed gathered in 1914. Fruit: best yellow-fleshed, nonmelting clingstone for canning in the East.

Brandywine.—Originated in Tulsa, Oklahoma, by Carl Burton Fox. Introduced commercially in 1943. Patent no. 580. Seedling of J. H. Hale; pollen parent unknown; selected in 1930. Fruit: large; seed small; flesh firm; develops characteristic flavor when canned; yellow, shaded red color.

Buttercup.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Lola x Arp; cross made in 1916. Fruit: flesh yellow; semiclingstone; small; very early; some value for local markets in the more northern districts.

Cumberland.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x Geensboro; cross made in 1914. Fruit: flesh white; almost a freestone; ripens at the same season as Golden Jubilee; most dependable white-fleshed peach for the cooler districts.

Curlew.—Originated in Long Beach, California, by John D. Davis. Introduced commercially in 1945. Patent no. 651. Open-pollinated seedling, probably of Salwey; selected in 1935. Fruit: ripens late, September 20 to October 10 at Ontario, California. Tree: requires less chilling than other late-ripening varieties.

Delicious.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x Greensboro; cross made in 1914. Fruit: flesh white; freestone; ripens just after Cumberland.

Dixigem.—Originated in Fort Valley, Georgia, by the United States Department of Agriculture (J. H. Weinberger). Introduced commercially in 1944. (Admiral Dewey x St. John) x South Haven; seedling planted in 1937. Fruit: early; nearly freestone; good texture and quality.

Dixigold.—Originated in Fort Valley, Georgia, by the United States Department of Agriculture (L. M. Hutchins). Introduced commercially in 1939. Open-pollinated seedling of Hiley; probably selected in 1931. Fruit: flesh yellow; freestone; resistant to bacterial spot; most nearly resembles Hiley.

Dixired.—Originated in Fort Valley, Georgia, by the United States Department of Agriculture (J. H. Weinberger). Introduced commercially in May, 1945. Halehaven x self; selected in 1939. Fruit: flesh yellow, firm; clingstone; matures early; appearance attractive.

Eclipse.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x self; seed gathered in 1914. Fruit: flesh yellow; freestone. Tree: hardier than Elberta. Formerly planted to replace Hiley in New Jersey.

Fireglow.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1939. J. H. Hale x Marigold; cross made in 1923. Fruit: flesh yellow; freestone; outstanding size, attractiveness, and quality. Tree: very sensitive to environment, hence not widely adapted.

Golden Blush.—Originated in Lakeside, California, by B. H. Haley. Introduced commercially in 1938. Patent no. 473. Parentage unknown; selected in 1925. Fruit: high flavor; ripens in same season as Elberta, which it resembles. Tree: more resistant to delayed foliation in southern California than Elberta.

Goldeneast *(New Jersey 87)*.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1937. Elberta x New Jersey 38 E. G.; cross made in 1923. Fruit: flesh yellow; freestone; ripens in midsummer; the most popular yellow-fleshed peach in southern New Jersey; has largely replaced Eclipse.

Golden Globe.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1937. J. H. Hale x Marigold; cross made in 1923. Fruit: flesh yellow; freestone; firm; very large. Tree: only medium in hardiness.

Golden Jubilee.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1926. Elberta x Greensboro; cross made in 1914. Fruit: flesh yellow; freestone; best of this class in many localities.

Goldfinch.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Slappey x Admiral Dewey; cross made in 1916. Fruit: flesh yellow; freestone, sometimes adhering a little; quality high; ripens with Golden Jubilee. Useful in breeding.

Halford No. 1 *(McKnight)*.—Originated in Modesto, California, by John Halford. Introduced commercially in 1921. Parentage unknown. Fruit: ripens 3 to 4 days before Halford No. 2; a commercial canning clingstone; flesh yellow. Tree: foliage with reniform glands.

Hardee.—Originated in Sandusky, Ohio, by D. S. Byers. Introduced commercially in 1936. Patent no. 120. Parentage unknown; selected in 1925. Fruit: flesh yellow; freestone; pronounced flavor; most nearly resembles an elongated Elberta. Tree: growth intermediate between J. H. Hale and Elberta; more resistant to cold than Elberta.

Hunter *(Hunter No. 1)*.—Originated in White Plains, New York, by Harry Hunter. Introduced for trial in 1930. Open-pollinated seedling, supposedly of Elberta; seed planted in 1910; first fruited in 1913; bud sticks received by the New York State Agricultural Experiment Station (U. P. Hedrick) for testing in 1914. Fruit: handsome; flesh yellow; freestone; good size, flavor, and quality; early midseason.

Hunter *(New York 50)*.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (U. P. Hedrick). Introduced for trial in 1924. Open-pollinated seedling of Hunter (Hunter No. 1); seed planted in 1915; first fruited in 1920. Fruit: midseason, a week or 10 days later than Hunter (Hunter No. 1); flesh yellow; freestone; good size and quality. Tree: mildews badly; foliage eglandular. Variety is now supplanted by parent Hunter (Hunter No. 1).

Hunter No. 1.—See **Hunter.**

Kirkman Gem *(Late Rio Oso Gem)*.—Originated in Madera, California, by Wm. T. Kirkman. Introduced commercially in 1946. Patent no. 506. Bud mutation of Rio Oso Gem; discovered in 1939. Fruit: flesh yellow; freestone; flesh firmer than Rio Oso Gem; flavor spicy; high color; 4 to 5 weeks later in maturity than Rio Oso Gem.

Late Rio Oso Gem.—See **Kirkman Gem.**

McGuigan.—Originated in Cedar Springs, Ontario, Canada, by J. C. McGuigan. Introduced commercially in 1920. Patent no. 624. Possibly a hybrid between Elberta and Chili; selected in 1920. Fruit: ripens earlier than Elberta; freestone; flesh yellow; resembles Elberta in size and shape.

McKnight.—See **Halford No. 1.**

Marigold.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Lola x Arp; cross made in 1916. Fruit: flesh yellow; semiclingstone; quality high; ripens about 1 week before Fisher. Tree: hardy.

Massasoit.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Slappey x Admiral Dewey; cross made in 1916. Fruit: flesh yellow; freestone; ripens with Triogem, but only medium firm. Tree: hardy; late blooming.

Meteor.—Originated in New Brunswick, New Jersey, by the New Jersey

Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x self; seed gathered in 1914. Fruit: flesh yellow; freestone; ripens just before Elberta.

Midway.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1939. J. H. Hale x New Jersey 27116; cross made in 1923. Fruit: flesh yellow; freestone; dark red blush; ripens just after Goldeneast.

Newday *(New Jersey 79)*.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1938. J. H. Hale x New Jersey 40 C. S.; cross made in 1923. Fruit: flesh yellow; semiclingstone; regarded by some New Jersey growers as the best yellow peach to follow Golden Jubilee.

New Jersey 79.—See **Newday.**

New Jersey 87.—See **Goldeneast.**

New Jersey 99.—See **Pacemaker.**

New York 50.—See **Hunter.**

Oriole.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Slappey x Admiral Dewey; cross made in 1916 at Vineland, Ontario, Canada. Fruit: flesh yellow; freestone; medium to large; quality high; ripens just before Golden Jubilee. Tree: vigorous and productive.

Pacemaker *(New Jersey 99)*.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1939. J. H. Hale x Marigold; cross made in 1923. Fruit: flesh yellow; semiclingstone; large; attractive; firm; extends the Goldeneast season.

Pioneer.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x Greensboro; cross made in 1915. Fruit: flesh white; almost a freestone; resembles Cumberland, which is now generally preferred.

Primrose.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x Elberta; cross made in 1915. Fruit: flesh yellow; freestone; large; ripens at same season as Summercrest.

Radiance.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Belle x Greensboro; cross made in 1914. Fruit: flesh white; almost a freestone; not equal to Delicious.

Raritan Rose.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1936. J. H. Hale x Cumberland; cross made in 1926. Fruit: flesh white; the best white freestone to ripen with Golden Jubilee where extreme winter hardiness is not necessary.

Redrose.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1940. J. H. Hale x Delicious; cross made in 1925. Fruit: flesh white; freestone.

Rosebud.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Carman x Slappey; cross made in 1916. Fruit: flesh white; semiclingstone; small; ripens 5 to 7 days before Cumberland or Raritan Rose. Tree: very hardy; prolific.

Sullivans Early Elberta.—Originated in Zebulon, Georgia, by P. M. Sullivan. Introduced commercially in 1938. Bud mutation of Elberta; discovered in 1933. Fruit: flesh yellow; freestone; ripens a week earlier than Elberta, which it closely resembles.

Summercrest.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1938. J. H. Hale x Cumberland; cross made in 1926. Fruit: flesh yellow; freestone; ripens just before Elberta; popular for local market in New Jersey.

Sunbeam.—Originated in New Brunswick, New Jersey, by the New Jersey

Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1925. Slappey x Admiral Dewey; cross made in 1916. Fruit: flesh yellow; semiclingstone; rather small but attractive; early; free from catechol tannin; used in breeding.

Sunhigh.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1938. J. H. Hale x New Jersey 40 C. S.; cross made in 1923. Fruit: flesh yellow; semiclingstone; large; firm; high-colored; very popular in the New York market.

Triogem.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1938. J. H. Hale x Marigold; cross made in 1923. Fruit: flesh yellow; an early, firm, high-colored freestone; ripens soon after Golden Jubilee.

White Hale.—Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (M. A. Blake). Introduced commercially in 1932. Patent no. 31. J. H. Hale x Belle; cross made in 1922. Fruit: flesh white; large; very firm; midseason freestone for districts south of New Brunswick, New Jersey.

PEAR

Cayuga.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (U. P. Hedrick). Introduced for trial in 1920. Open-pollinated seedling of Seckel; seed borne in 1906. Fruit: of Bartlett size; similar in shape to Seckel; color of Clairgeau. Tree: has some blight resistance.

Caywood.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (U. P. Hedrick). Introduced for trial in 1938. Open-pollinated seedling of Seckel; seed collected in 1908; first full crop in 1922. Fruit: larger, rounder, and more russeted than Seckel; sweet, highly aromatic, Seckel flavor; season a little after Early Seckel.

Clyde.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (U. P. Hedrick). Introduced for trial in 1932. Open-pollinated seedling of Seckel; seed collected in 1908; first full crop in 1921. Fruit: larger, less obovate, longer necked than Seckel; skin light greenish-russet over entire surface; flavor not as rich as Seckel; season 2 to 3 weeks later than Seckel; fruit keeps longer than Seckel.

Covert.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1935. Bartlett x Dorset; cross made in 1912; first full crop in 1921. Fruit: one of largest of all pears; similar to Bartlett but not as pale yellow; flesh tender, granular; fair for eating, better as canning and shipping sort; season November through December.

Early Seckel.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (U. P. Hedrick). Introduced for trial in 1935. Open-pollinated seedling of Seckel; seed collected in 1906; first full crop in 1915. Fruit: resembles Seckel but ripens 2 to 3 weeks earlier; keeps in storage longer than Seckel; recommended for local and roadside markets.

Ewart.—Originated in East Akron, Ohio, by Mortimer Ewart. Introduced commercially in 1928. Parentage unknown. Fruit: size medium; quality good; skin greenish yellow, netted with russet; flesh fine, melting, tender, juicy; season 2 to 3 weeks later than Bartlett which it most nearly resembles. Tree: blight resistance unknown.

Gorham.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Bartlett x Josephine de Malines; cross made in 1910. Fruit: ripens 1 month later than Bartlett; keeps 6 to 8 weeks longer than Bartlett; quality excellent; most nearly resembles Bartlett.

Guraly Jr.—Originated in Fairport Harbor, Ohio, by Joseph T. Guraly, Jr. Introduced commercially in 1940. Patent no. 435. Parentage unknown. Fruit: ripens early (early August); flesh white with red streaks radially from core.

Orient *(P. I. 64224)*.—Originated in Chico, California, by the United States Department of Agriculture (Walter Van Fleet). Introduced commercially in 1945 through the Tennessee Agricultural Experiment Station. *Pyrus communis*

x *Pyrus* sp. from China; direction of cross unknown. Fruit: firm; juicy; slightly sweet; lacking in flavor; nearly round; ripens August 15 to 18 at Knoxville, Tennessee; good for canning. Tree: free from blight; produces medium annual crops; mostly of interest in Tennessee and southward.

Ovid.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1931. Bartlett x Dorset; cross made in 1912. Fruit: large; color resembles Bartlett but has russet patches; flesh fine-grained, tender, nearly white, sweet, agreeably flavored; quality good; ripens in December at Geneva; most nearly resembles Dorset.

P. I. 64224.—See **Orient.**

Phelps.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1925. Winter Nelis x Russet Bartlett; cross made in 1912. Fruit: ripens much later than Bartlett, around Thanksgiving, and keeping until Christmas; color duller than Bartlett; pleasant vinous flavor; flesh juicy, tender.

Pulteney.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1925. Winter Nelis x Russet Bartlett; cross made in 1912. Fruit: ripens 4 weeks later than Bartlett with fruits a little more regular in outline, skin smoother, but not as attractive in color as Bartlett.

Royal Red.—Originated in Milpitas, California, by Victor A. Silvera. Introduced commercially in 1940. Patent no. 380. Bud mutation of Hardy; discovered in 1934. Identical with parental type except for the red skin color of the mature fruit.

USDA 66131.—See **Waite.**

Waite (*USDA 66131*).—Originated in Arlington, Virginia, by the United States Department of Agriculture (M. B. Waite). Introduced commercially in 1938. Parentage unknown; selected about 1920. Fruit: almost as large as Bartlett, which it resembles in shape; ripens about Kieffer time; flesh smooth, almost free of grit cells; more acid than Bartlett; excellent for cooking and canning, fairly good for dessert. Tree: good blight resistance; rather weak type of growth; cross pollination essential.

Willard.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1931. Bartlett x Dorset; cross made in 1912. Fruit: ripens 2 weeks later than Ovid; resembles Bartlett in shape and color; surface uneven; flesh yellowish, fine-grained, tender, juicy, with a piquant flavor; quality good.

Pecan

Fisher.—Originated in New Memphis, Illinois, by Jacob Fisher. Introduced commercially in 1938. Parentage unknown; a seedling tree selected by Joseph Gerardi of O'Fallon, Illinois. Nut: flavor good; size medium; good cracker. Tree: heavy bearer.

Persian Walnut

Littlepage.—Originated in Wassaic, New York, by Gilbert L. Smith and Wm. A. Benton. Introduced commercially in 1945. Parentage unknown; seed planted in 1935; fruited in 1944. Nut: shell thin; size and quality good; early maturing. Tree: hardy.

Persimmon

Jumbu.—Originated in Fullerton, California, by J. M. Alcorn. Introduced commercially in 1938. Parentage unknown: selected about 1930. Fruit: non-astringent; very large; resembles Hyakume in shape, Fuyu in type. Probably identical with the Japanese variety Hana Fuyu.

Plum

Albion.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1929. Golden Drop x Grand Duke; cross made in 1908; seed germinated in 1909. Fruit: purplish black; stone clings tenaciously; flesh a little coarse and stringy; ripens late; quality better than Grand Duke which it most nearly resembles.

American Mirabelle.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1925. Imperial Epineuse x Mirabelle; cross made in 1911; seed germinated in 1912. Fruit: golden yellow color of Mirabelle, but of larger size; flavor good; for dessert or culinary use; most nearly resembles Mirabelle.

Eugene.—Originated in Elk Grove, California, by Claude Tribble. Introduced commercially in 1944. Apparently an open-pollinated seedling of a Japanese-type plum; selected in 1940. Fruit: of large size and good quality. Tree: very productive.

Grenville.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1941. Burbank x *Prunus nigra;* selected in 1932. Fruit: quality excellent; Japanese type; large, red; most nearly resembles Burbank. Tree: very hardy.

Hall.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Golden Drop x Grand Duke; cross made in 1908; seed germinated in 1909. Fruit: large; attractive; quality good; most nearly resembles Grand Duke.

Improved Satsuma.—See **Mariposa.**

Late President.—Originated in Le Grand, California, by F. W. Anderson. Introduced commercially in 1944. Patent no. 573. Bud mutation of President; discovered in 1935. Fruit: ripens about 2 weeks later than President, otherwise identical with parental type.

Mariposa *(Improved Satsuma).*—Originated in Pasadena, California, by Mrs. J. B. Thompson. Introduced commercially in 1935. Patent no. 111. Parentage unknown; selected as a seedling in 1923. Fruit: sweeter than Satsuma, which it resembles. Tree: resistant to delayed foliation in southern California.

Stanley—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1926. Agen x Grand Duke: cross made in 1912: seed germinated in 1913. Fruit: appearance attractive; ripens 1 week earlier than Italian: most nearly resembles prune type of fruit; better in fruit and tree than Italian. Tree: more reliable in bearing and more adaptable than Italian.

RASPBERRY

Brant.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1925. Smith No. 1 x June: cross made in 1912. Fruit: purple, large, handsome, firm, holds up well, of good quality. Now out of cultivation because of mosaic.

Bristol.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1934. Watson Prolific x Honeysweet: cross made in 1921. Fruit: black, large, firm, fairly glossy, attractive, quality excellent: season 1 week earlier than Naples. Bush: hardy, vigorous; bears heavy crops. Now widely planted as one of the best varieties.

Cayuga.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1922. June x Cuthbert: cross made in 1910. Fruit: red: ripens before Cuthbert, which it resembles. Bush: productive; suckers heavily. Variety now superseded by better sorts.

Dundee.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1927. Smith No. 1 x Palmer; cross made in 1910. Fruit: black: large, glossy, small drupelets, attractive, moderately firm, mildly subacid, quailty very good. Bush: tall, vigorous, productive: moderately resistant to mosaic.

Evans.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1936. Watson Prolific x Honeysweet: cross made in 1921. Fruit: black; high quality, very glossy, appearance attractive, only moderately firm. Little grown in New York: considered promising in southern California.

Gatineau *(0-276).*—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1943,

Lloyd George x Newman; selected in 1931. Fruit: red; early ripening.

Indian Summer.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1936. New York 1950 (Empire x Herbert) x Lloyd George; cross made in 1925; seedling first fruited in 1928. Fruit: red; very aromatic; crumbles frequently; useful for jam; superior to Ranere (St. Regis) and Erskine Park; quality good as an autumn-fruiting variety. Bush: very productive; escapes mosaic infection. Planted extensively in home gardens.

Johnson Everbearing.—Originated in Davis, West Virginia, by A. W. Johnson. Introduced commercially in 1945. Parentage unknown; discovered in 1934, supposedly as a wild plant. Fruit: black; large. Plant: pronounced fall-bearing habit; most nearly resembles Cumberland.

Lloyd George.—Originated as a chance seedling in a wood in Dorsetshire, England. Introduced in England by J. J. Hettle, Corbe Castle, Dorset, England. Introduced for trial in the United States in 1929 by the New York State Agricultural Experiment Station. Parentage unknown. Fruit: red; quality excellent; variety considered very promising in 1928 but now sparingly grown. An outstanding parent in breeding new varieties.

Madawaska *(0-272)*.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1943. Lloyd George x Newman; selected in 1931. Fruit: dark red; excellent canner; early ripening. Plant: hardy.

Marcy.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1936. Lloyd George x Newman; seedling first fruited in 1928. Fruit: red; extremely large, firm, thick-fleshed; flavor mild; quality good but too dark in color when fully ripe. Bush: lacks hardiness; escapes mosaic.

Marion.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1937. Bristol x New York 2585 (Newman x Herbert); selected in 1930. Fruit: purple; large; moderately juicy; firm, tart; quality good; season late, 1 week after Sodus. Bush: resembles red raspberry in habit.

Milton.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (George L. Slate). Introduced for trial in 1942. Lloyd George x Newburgh; cross made in 1927. Fruit: red; compares well with better varieties, and escapes mosaic.

Monroe.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Few sent out for trial in 1932. Newman x Cuthbert; cross made in 1921. Fruit: red; firm; quality and flavor excellent, but more acid than Cuthbert; ripens about 1 week before Cuthbert. Variety never formally introduced and now superseded by better ones.

Naples.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1932. Honeysweet x Rachel; cross made in 1921. Fruit: black; large, firm, glossy, attractive; quality good; season 1 week later than Bristol. Bush: vigorous, productive, hardy, susceptible to mosaic. Plantings are decreasing.

Newburgh.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1929. Newman x Herbert; cross made in 1922. Fruit: red; very large and firm; bright, attractive color; keeping and shipping quality very good; ripens 3 to 4 days earlier than Cuthbert. Bush: mosaic is rarely serious. An important commercial variety.

Newman *(Newman 23)*.—Originated at Ville La Salle, Quebec, Canada, by C. P. Newman. Introduced commercially in 1924. Parentage unknown; selected about 1918. Fruit: red; large; flavor mild; season with or a little later than Cuthbert. Plant: susceptible to mosaic. Variety now almost obsolete.

Newman 23.—See **Newman.**

0-262.—See **Rideau.**

0-264.—See **Trent.**

0-272.—See **Madawaska.**

0-275.—See **Ottawa.**

0–276.—See **Gatineau.**

Ottawa *(0–275).*—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1943. Viking x (Logan x Ranere); selected in 1931. Fruit: red; firm; good shipper. Most nearly resembles Viking.

Owasco.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1922. June x Cuthbert; cross made in 1910. Fruit: red; excellent in every way. Bush: poor plant-maker; not too hardy; variable in growth habit. Variety now eliminated by mosaic.

Rideau *(0–262).*—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1943. Lloyd George x Newman; selected in 1931. Fruit: red; firm; good shipper; bright and attractive.

Seneca.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1922. June x Cuthbert. Fruit: red. Bush: almost identical with Cayuga, but plants not as tall, with fewer prickles; at one time recommended to precede and to take the place of Cuthbert; susceptible to mosaic, which has now eliminated it.

Sodus.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (George L. Slate). Introduced for trial in 1935. Dundee (black raspberry) x Newburgh (red raspberry); cross made in 1927. Fruit: purple; large, firm, medium color; sprightly; quality good but not equal to Columbian; season shortly after Latham. Bush: very vigorous, very productive, hardy; more resistant to drought than Columbian; free from mosaic, but variety is susceptible to it and verticillium wilt. Now an important commercial variety.

Taylor.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1935. Newman x Lloyd George; cross made in 1925. Fruit: red; ripens with Latham; very large; color bright, attractive; does not crumble, does not cling to bush; withstands handling; quality high. Bush: vigorous, productive, tall, increases rapidly; more subject to mosaic than Newburgh.

Tennessee Luscious *(Tennessee X37).*—Originated in Knoxville, Tennessee, by the Tennessee Agricultural Experiment Station (Brooks D. Drain). Introduced commercially in 1944. Patent no. 653. Lloyd George x Tennessee VVF 169 (Van Fleet x Viking). Fruit: large, firm; conic; medium red, glossy; drupelets strongly coherent; subacid; flavor very good; season late; most nearly resembles Cuthbert.

Tennessee X37.—See **Tennessee Luscious.**

Trent *(0–264).*—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1943. Newman x Lloyd George; selected in 1931. Fruit: red; early maturing. Plant: hardy.

Webster.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced commercially in 1926. Smith No. 1 black raspberry x an unknown purple raspberry seedling; cross made in 1910. Fruit: size medium; color dark, dull purple; firm; tart; quality fair. Plants: slow growing; not very productive. Plantings are increasing in Erie County, New York.

Strawberry

Beacon.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. President x Marshall; cross made in 1910. Fruit: ripens with Dunlap. Plant: unproductive and blossoms susceptible to frost. Now an obsolete variety.

Bliss.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Chesapeake x Atkins Continuity; seed borne in 1911. Fruit: ripens late; quality excellent. Plant: withstands drought well, but lacks vigor and productivity. Almost obsolete.

Boquet.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1923. Chesapeake x Pan American; cross made in 1911. Fruit: large, light red; ripens in midseason; flowers perfect; quality good, but not as good as Bliss. Plant: runner production scanty. Almost obsolete; superseded by more recent varieties superior in vigor and productivity.

Caledonia.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced commercially in 1931. Marshall x Howard 17; cross made in 1923. Fruit: large; attractive; firm; flesh red; quality good; made an excellent preserve for which purpose it was introduced. Plant: numerous plant maker; vigorous; productive; eventually proved too susceptible to leaf-spot and is probably out of cultivation.

California 403.8.—See **Shasta.**

California 537.5.—See **Sierra.**

California 544.2.—See **Lassen.**

California 567.6.—See **Tahoe.**

California 579.4.—See **Donner.**

Camden.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1931. Marshall x Howard 17; cross made in 1923. Fruit: large; holds up well in size; glossy, attractive; flavor mild; quality fairly good; when overripe, color tends to darken. Only sparingly grown.

Cato.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1931. Marshall x Howard 17; cross made in 1923. Fruit: quality nearly equals Marshall and much superior in plant characters; large; attractive, but bruises very easily. Plants: vigorous and productive; home garden variety. Now superseded by other varieties.

Catskill.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1934. Marshall x Howard 17; cross made in 1923; selected in 1925. Fruit: large; mid-season; slightly irregular; moderately firm; dark red, glossy, attractive; mildly subacid; quality good. Plant: very vigorous and productive. Widely grown from Maryland north.

Clermont.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1931. Marshall x Howard 17; cross made in 1923; selected in 1925. Fruit: excellent for market and home use; very large, holds up well in size through season; regular in shape; very glossy, attractive, does not bruise easily; quality excellent. Plant: somewhat susceptible to leafspot.

Culver.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1931. Marshall x Howard 17; cross made in 1923; selected in 1925. Fruit: color dark; large; regular in shape; bruises slightly; flavor sprightly; quality very good; ripens early midseason; well adapted for preserves and home use.

Donner *(California 579.4)*.—Originated in Wheatland, California, by the California Agricultural Experiment Station (Harold E. Thomas and Earl V. Goldsmith). Introduced commercially in 1945. Cal. 145.52 [Cal. BH-14 (mixed crosses) x Redheart] x Cal. 222 [Cal. 66.2 (USDA 634 x Banner) x Cal. 7.20 (Blakemore x Nich Ohmer)]; selected in 1938. Fruit: high dessert quality; good fresh market berry.

Dresden.—Originated in Geneva, New York, by the New York State Agricultural Experiment Station (George L. Slate). Introduced for trial in 1939. Beacon x Howard 17; cross made in 1929; selected in 1931. Fruit: light red, smooth; maintains size throughout the season; few or no nubbins. Plant: best adapted to northern tier of states and Canada; very productive; crown appears to lack hardiness.

Elgin *(0-271)*.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1944. Ettersburg 214 x Wm. Belt; selected in 1940. Fruit: ripening very late. Plant: resistant to leafspot; perfect flowers. Variety most nearly resembles Ettersburg 214.

Green Mountain.—Originated in Putney, Vermont, by George D. Aiken. Introduced commercially in 1935. Patent no. 112. Open-pollinated seedling of Superb Everbearing. Fruit: similar to Howard 17 but matures about one week later. Plant: has everbearing characteristics.

Klonmore.—Originated in Baton Rouge, Louisiana, by the Louisiana State University Experiment Station (Julian C. Miller). Introduced commercially in 1940. Blakemore x Klondike; selected in 1935. Fruit: matures over a long season; excellent shipper; good for quick-freezing process. Plant: resistant to leafspot and scorch. Resembles Blakemore.

Konvoy.—Originated in Baton Rouge, Louisiana, by the Louisiana State University Experiment Station (Julian C. Miller). Introduced commercially in 1942. Fairmore x Klondike; selected in 1938. Fruit: yields are high. Plant: resistant to leafspot and scorch. Resembles Klondike.

Lassen *(California 544.2)*.—Originated in Wheatland, California, by the California Agricultural Experiment Station (Harold E. Thomas and Earl V. Goldsmith). Introduced commercially in 1945. Cal. 21.9 [Blakemore x Cal. Z9 (Banner x Fendalcino)] x Cal. 161.1 {Nich Ohmer x Cal. 86.6 [USDA 634 x Cal. Z11 (Banner x Fendalcino)]}; selected in 1938. Plant: long-lived; resistant to virus diseases; high production.

Louise.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1942. Ettersburg 80 x self; selected in 1933. Fruit: ripens very late; quality high. Plant: flowers imperfect.

Mackenzie.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1941. Excelsior x Howard 17; selected in 1934. Fruit: about same season as Howard 17. Plant: flowers perfect; more productive under certain conditions than Howard 17, which it most nearly resembles.

Marion Bell.—Originated in Baton Rouge, Louisiana, by the Louisiana State University Experiment Station (Julian C. Miller). Introduced commercially in 1946. Fairmore x self; selected in 1942. Fruit: matures over a long period of time; flavor excellent; good shipper; color bright. Plant: resistant to leafspot and scorch. Most nearly resembles Klonmore.

Mastodon.—Originated in Peru, Indiana, by George Voer. Introduced commercially in 1921. Superb x Kellogg; selected in 1917. Fruit: large, somewhat variable and irregular; quality good; colors somewhat unevenly. Plant: very vigorous, productive, superior to Progressive and Superb; autumn cropper.

0-271.—See **Elgin.**

Paymaster.—Originated in Sawyer, Michigan, by B. W. Keith. Introduced commercially in 1942. Howard 17 x Gem Everbearer; selected in 1937. Fruit: firm; good shipper, canner, and for deep freezing. Plant: productive; resistant to red stele disease; spring fruiting.

Shasta *(California 403.8)*.—Originated in Davis, California, by the California Agricultural Experiment Station (Harold E. Thomas and Earl V. Goldsmith). Introduced commercially in 1945. Cal. 67.5 (Nich Ohmer x USDA 634) x Cal. 177.21 [USDA 543 x Cal. 68.24 (USDA 634 x N.Y. 4626)]. Plant: widely adapted in central coast area of California; fair resistance to virus diseases and verticillium wilt.

Sierra *(California 537.5)*.—Originated in Davis, California, by the California Agricultural Experiment Station (Harold E. Thomas and Earl V. Goldsmith). Introduced commercially in 1945. Nich Ohmer x Cal. 177.21 [USDA 543 x Cal. 68.24 (USDA 634 x N.Y. 4626)]; selected in 1937. Plant: fair resistance to virus disease.

Streamliner.—Originated in Lostine, Oregon, by Roy C. Edgmand. Introduced commercially in 1944. Parentage unknown; discovered in 1938. Fruit: firm; good keeper for home use. Plant: hardy; heavy spring cropper; everbearer; makes runners freely.

Suwannee.—Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in September, 1945. Missionary x Howard 17; cross made in 1931; selected in 1933. Fruit: its ability to develop high flavor and quality under adverse weather conditions when most varieties are quite deficient in these qualities.

Plant: resembles Southland in adaptation, uses, and limitations; adapted to home gardens.

Tahoe *(California 567.6)*.—Originated in Wheatland, California, by the California Agricultural Experiment Station (Harold E. Thomas and Earl V. Goldsmith). Introduced commercially in 1945. Cal. 144.21 (Narcissa x Nich Ohmer) x Cal. 143. 32 [Narcissa x Cal. BH–14 (mixed crosses)]; selected in 1938. Fruit: ripens late. Plant: fair resistance to virus diseases.

Tupper.—Originated in Ottawa, Ontario, Canada, by the Division of Horticulture, Central Experimental Farm. Introduced commercially in 1942. Ettersburg 214 x Cassandra; selected in 1934. Fruit: late; valuable for home use and local markets. Plant: flowers imperfect; very productive. Variety most nearly resembles Ettersburg 214.

Wyona.—Originated in Bedford, Virginia, by A. S. Johnson. Introduced commercially about 1923. Perhaps an open-pollinated seedling of Gandy; selected prior to 1922. Fruit: flesh firm; quality good for a subacid berry; long keeper; late maturity. No longer planted.

Tangelo

Broward.—Originated in Eustis, Florida, by the United States Department of Agriculture (F. W. Savage). Introduced commercially in 1939. Bowen grapefruit x Dancy tangerine; selected in 1912. Fruit: medium to large; quality good; ripens during December and January at Eustis.

Lake.—See **Orlando.**

Minneola.—Originated in Eustis, Florida, by the United States Department of Agriculture (E. M. Savage). Introduced commercially in 1931. Bowen grapefruit x Dancy tangerine; selected in 1912. Fruit: juicy; flavor fine; color very attractive; ripens in January and February at Eustis.

Orlando *(Lake)*.—Originated in Eustis, Florida, by the United States Department of Agriculture (E. M. Savage). Introduced commercially in 1931; trademarked Orlando. Bowen grapefruit x Dancy tangerine; selected in 1912. Fruit: matures early, November to February; size small to medium; flavor fine; well colored. One of the best tangelo varieties.

Sampson.—Originated in Eustis, Florida, by the United States Department of Agriculture (Walter T. Swingle and H. J. Webber). Introduced commercially in 1904; named in honor of F. G. Sampson, Boardman, Florida. Grapefruit x Dancy tangerine; cross made in 1897. Fruit: thin-skinned, bruises easily; good for juice and marmalade; season February to April. Tree: resistant to gummosis; promising as a rootstock for orange and lemon.

San Jacinto.—Originated in Indio, California, by the United States Department of Agriculture (Walter T. Swingle). Introduced commercially in 1931. F_2 hybrid seedling of unknown tangelo; most nearly resembles Orlando; from the same parentage as Thornton. Fruit: quality fair; early ripening; more resistant to handling than Thornton.

Seminole.—Originated in Eustis, Florida, by the United States Department of Agriculture (E. M. Savage). Introduced commercially in 1931. Bowen grapefruit x Dancy tangerine; selected in 1912. Fruit: matures late, February to April; attractive; medium sized; most nearly resembles Orlando, but more acid.

Webber.—Originated in Eustis, Florida, by the United States Department of Agriculture (E. M. Savage). Introduced commercially in 1932. Bowen grapefruit x Dancy tangerine; selected in 1909. Fruit: flavor fine; very juicy; size medium; flat; skin smooth, thin, orange-colored; ripens December to February. Named for H. J. Webber, who deemed it one of the best of the tangelos.

Wekiwa.—Originated in Eustis, Florida, by the United States Department of Agriculture (E. M. Savage). Introduced commercially in 1931. Trade marked Wekiwa. Bowen grapefruit seedling 37 x Sampson tangelo; selected in 1909. Fruit: small, sweet, pink-fleshed; attractive and pleasing taste; ripens during December and January.

Tangor

Altoona.—See **Umatilla.**

Umatilla *(Altoona)*.—Originated in Eustis, Florida, by the United States

Department of Agriculture (E. M. Savage). Introduced commercially in 1931; trademarked Umatilla. Satsuma mandarin x Ruby orange; selected in 1912. Fruit: a very good late variety, ripening January to March; sweeter than the Seminole tangelo; most nearly resembles the Tangelo group.

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NAMES OF PATENTED VARIETIES

Patent Number	*Varietal Name*
31	White Hale, peach
53	Ruby, grapefruit
88	Bonnet Seedless, grape
92	Garden State, nectarine
100	Gano, avocado
111	Mariposa, plum
112	Green Mountain, strawberry
120	Hardee, peach
124	Armstrong Seedless Valencia, orange
126	Robertson Navel, orange
234	Henry's Select, avocado
278	Red Graham, apple
293	Red Sriped Graham, apple
328	Violet, nectarine
342	Armstrong Seedless, lemon
347	Summernavel, orange
380	Royal Red, pear
435	Guraly Jr., pear
444	Idemor, lime
473	Golden Blush, peach
506	Kirkman Gem, peach
548	Paradise Navel, orange
570	Tennessee Shipper, strawberry
573	Late President, plum
575	Bim, nectarine
576	Mary Martin, avocado
580	Brandywine, peach
587	Hayes Late, nectarine
619	Baxters Black Winesap, apple
624	McGuigan, peach
625	Dream Navel, orange
627	Late Lambert, cherry
628	Tomko, avocado
635	Bowen, blackberry
651	Curlew, peach
653	Tennessee Luscious, raspberry
656	Ott, cherimoya
658	Humboldt, crab apple
662	Graham, avocado

ALPHABETICAL LIST OF VARIETY NAMES INCLUDED IN LIST NO. 2

Adams, elderberry
Afterglow, peach
Albion, plum
Almission, grape
Alton, apple
Altoona, tangor. See Umatilla
Ambergem, peach
American Mirabelle, plum
Armstrong Seedless, lemon
Armstrong Seedless Valencia, orange
Astrachan No. 2391, apple. See Carlton
Baxters Black Winesap, apple
Beacon, strawberry
Beall, fig
Betty, papaya
Beverly Hills, apple
Bim, nectarine
Bliss, strawberry
Bonnet Seedless, grape
Bonnet Seedless Muscat, grape
Boquet, strawberry
Bowen, blackberry
Brag, filbert
Brandywine, peach

Tomko, avocado
Tradescant Heart, cherry. See Noble
Trent, raspberry
Triogem, peach
Tupper, strawberry
Umatilla, tangor
USDA 57, apple. See Close
USDA 66131, pear. See Waite
USDA Rixford 2830, fig.
See Kearney
Violet, nectarine
Waite, pear
Wareham, blueberry
Webber, tangelo
Webster, apple
Webster, raspberry
Wekiwa, tangelo
Weymouth, blueberry
White Hale, peach
Willard, pear
Workman Navel, orange.
See Summernavel
Wyona, strawberry
Zellwood Satin, orange
Zill, mango
Zutano, avocado

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